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BRITISH LIFEBOATS.

Two very prominent objects in the nave of the present Liverpool Exhibition are the full sized lifeboats contributed by the Royal National Lifeboat Institution and by Messrs. Forrestt & Son, of Limehouse, who are the builders of both boats, their own exhibit departing in some particulars from that built to the designs of the Chief Inspector of Lifeboats, the Hon. Captain Chetwynd, R.N. This latter boat is intended to be stationed at Lytham, at the mouth of the Ribble, when the Exhibition is closed, and will replace the existing one, which has rendered excellent services.

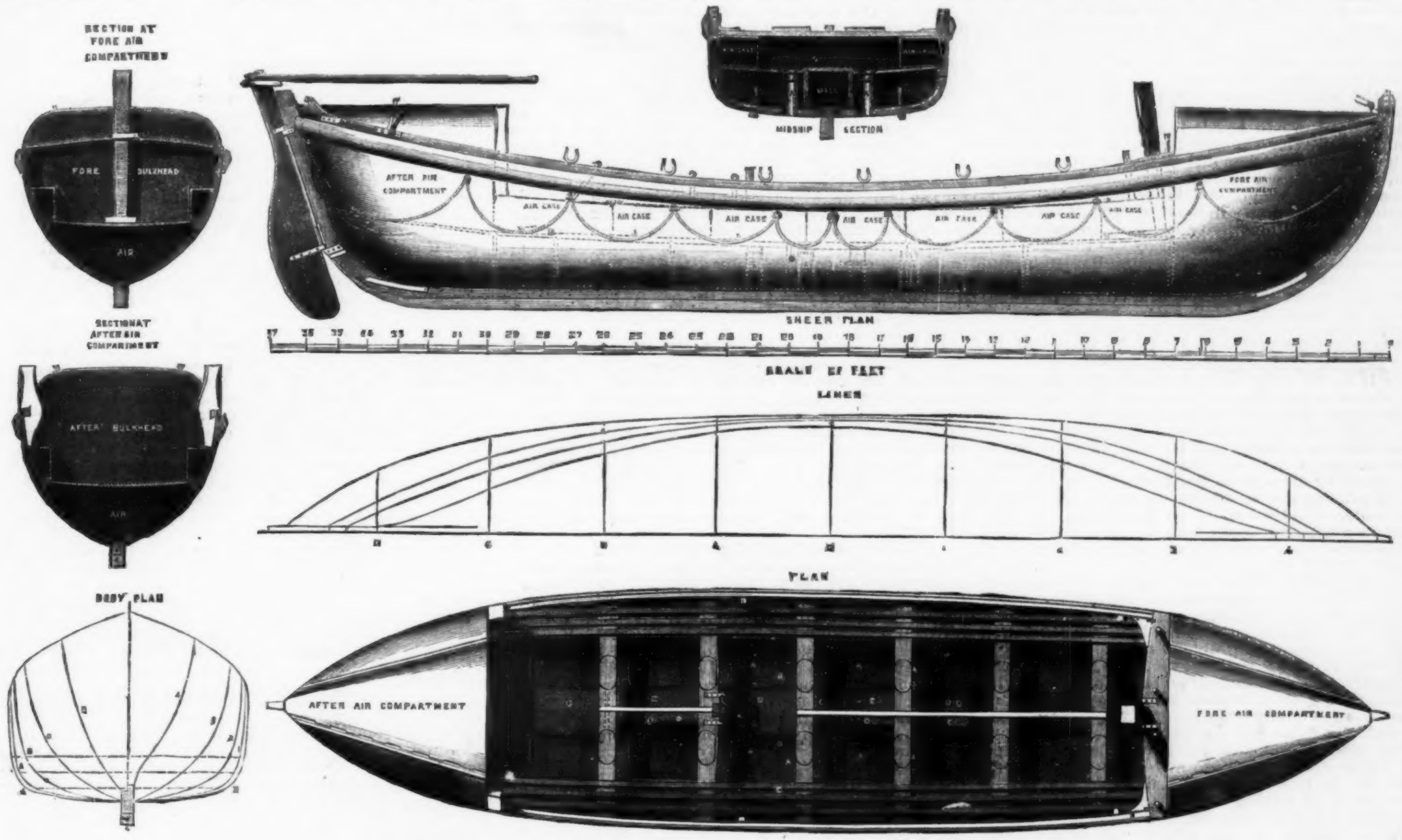
We publish, from *The Engineer*, engravings of this boat, which are interesting as showing the form considered to be the best adapted for its purpose by the officials of the Lifeboat Institution, although the boats are made of various sizes to suit the particular requirements of the stations to which they are sent. The largest class, which are always kept afloat at stations like Ramsgate and New Brighton, measure 46 ft. by 11 ft., and one experimental boat, stationed at Clacton-on-Sea, has been fitted with an iron centerboard or drop keel, which has been found to materially improve her sailing qualities.

The dimensions of the boat exhibited are as follows: Length over all, 37 ft.; beam, extreme, 8 ft.; depth amidships, from under side of iron keel to upper side of gunwale, 4 ft. 2 in.; depth at stem and stern posts, 6 ft. 10 in.; the iron and wood keels are both 4 in. deep. On the drawing, A indicates the relieving valves for clearing the deck of water, B scuttle for pumping water out of bilges and ventilating them, C water ballast tanks, D plugs in bottom for filling the tanks, E pumps for emptying the ballast tanks.

This boat is built on the self-righting and self-emptying principle adopted by the Royal National Lifeboat Institution. The skin of the hull consists of two thicknesses of bare ½ in. Honduras mahogany with a layer of painted calico between; the two layers of plank go diagonally from gunwale to gunwale, one skin crossing the other, except at the bow and stern, where the angle at the keel is too sharp; here it is butted into a rabbet in the ordinary way, immense strength being gained by this system. The self-righting is effected by means of the two air cases at the ends, which support the boat if capsized, and the heavy iron keel, which prevents her remaining bottom up, and at the same time gives her very great lateral stability and resisting power against capsizing. The weight of the iron keel varies with the dimensions of the boat; in boats of this class it is about 13 cwt. The self-emptying is secured by a deck being laid from 2 in. to 4 in. above the load water-line, with six or eight tubes going down through the bottom, their upper ends in the deck being closed from water coming up from below through the motion of the boat or other causes, by means of self-acting valves that open downward only.

The space under the deck is filled with very light wooden cases covered with calico ironed on hot with marine glue, for the purpose of preserving the buoyancy of the boat if she meets with an accident. There it also a series of air cases of the same nature along each side from the deck to the thwarts, which also diminish materially the space capable of containing water when a sea breaks into the boat; the end cases are also divided into three compartments. The boat is fitted with four water-ballast tanks running along the keel, to be used when in deep enough water to admit of immersing the boat more, and so giving her greater stability.

Each tank is separate from the others, and has its own plug for running the water in, and pump for pumping it out, either of which operations can be performed in one minute; the boat, if completely filled by a sea breaking into her, will free herself in one minute. The transporting carriage is of the model adopted by the Institution, and forms not only a means of conveyance to the scene of a wreck, but also the best auxiliary for launching the boat upon arriving there. The bed pole, or trail, is formed of two sides having rollers between them, on which the keel of the boat rests, the bilge pieces resting on longitudinal pieces of the carriage placed for that purpose. The boat is put on the carriage with the stern toward the shafts; the carriage then being pushed into the water far enough for the boat to be afloat when off it, the boat is launched by means of self-detaching ropes for the purpose. To replace the boat on the carriage, the forebed is taken away and the end of the trail laid on the ground, thus forming an inclined plane up which to draw the boat. When the boat is in her place on the trail, the carriage is so nearly balanced that it is easily lifted to replace the fore-carriage.



LIFEBOATS AT THE LIVERPOOL EXHIBITION.

STEAM LIFEBOATS.—AN OPPORTUNITY FOR INVENTORS.

DURING the last meeting of the Institute of Naval Architects, the question of using steam lifeboats was made the subject of a very interesting and useful discussion. Messrs. Benjamin and Taylor have designed a very ingenious steam lifeboat, and they read a paper describing it, and exhibited a model. The boat in question is, of course, intended to be unsinkable, and, as we understand the description, she is also to be uncapsizable. A shallow hull has a rounded structure built on the top of it, within which the rescued crew of a ship are to find shelter, safety, and even a warm bath. Propulsion is effected by screws under the bottom of the boat, and partly incased in semi-circular tunnels, excavated, so to speak, in the floor of the hull. So far as can be seen, the craft does not possess any of the characteristics that a lifeboat, as the term is now understood, has. But, whatever the defects of the scheme, it possessed the advantage that, as we have said, it elicited a very good discussion.

It can hardly have failed to strike thoughtful people that oars and men are in many respects the worst propelling agents that could be employed in working a lifeboat; and numerous proposals have been made for using steam instead. It is of the utmost importance that a lifeboat should get alongside a wreck as soon as possible; but hours are now spent in pulling from the shore to a wreck, when each minute may mean a life lost. Indeed, so fully is the inadequacy of manual power recognized, that at all large and important lifeboat stations, such, for example, as Ramsgate, the lifeboat is invariably taken out by a tug steamer to windward of the wreck, down to which the lifeboat then drops. When a rescue has been effected, her sails are hoisted, and she runs for a port. But there are dozens of lifeboat stations where no tug is available; and in not a few cases the lifeboat has been unable to do any good, simply because she could not be rowed or sailed to the wreck. It is not too much to say that if lifeboats could be provided with steam power, a very large number of lives now lost each year would be saved. There is consequently the greatest possible stimulus to invention, and nothing, we believe, but the utter hopelessness of the task has prevented inventors from solving the problem set before them. No doubt the magnitude and exceeding difficulty of the problem are not fully realized. Captain Chetwynd, of the National Lifeboat Institution, a man of over thirty years' special experience, set these difficulties very clearly before the Institute of Naval Architects, and when he sat down his hearers must have felt certain that, whatever power may yet be used for the intended purpose, steam cannot be employed. Captain Chetwynd explained that none but those who have, like himself, been personally engaged in lifeboat work can form any adequate conception of the force and fury of the waves on, for example, the Goodwin Sands. It is easy to talk about metacenters, and centers of gravity, and buoyancy; but in a heavy confused sea, the laws of stability seem to be in abeyance. Over and over again, a 30 foot lifeboat stands literally on end against a sea. On two occasions, lifeboats have been turned clean over endwise. To say that they roll their gunwales under is nothing. The motion in them is simply inexpressibly violent, and apparently taking place in every direction at once. Apart from this, the seas continually break into them with tremendous violence. "When," said Captain Chetwynd, "I have often urged a boat's crew to go off in a heavy gale, they have met my expostulations

with the argument, 'Our backs would be broken by the seas falling into the boat.'" He had experience of cases in which a breaker has tumbled over the bows of a boat, without the slightest injury to men forward of midships, while the men in the stern were maimed or disabled by the smash of tons of water into her stern; those forward being saved by the sea leaping clean over their heads. In addition to this, the boat must not draw 3 feet, or she cannot get through the shallow water of breakers to go alongside a wreck. On the Goodwin Sands, the lifeboats on a draught of but 3 feet are constantly thumped down on the bottom when they get in the trough between two waves. The graphic picture drawn by Captain Chetwynd places the indomitable courage and hardiness of our lifeboat crews in a stronger light than ever. Most of his hearers for the first time in their lives realized the character of the work done night after night on our coasts, and the wonderful qualities of the boats themselves. The National Lifeboat Institution possesses 270 self-righting boats. These latter craft have gone out 4,700 times, and saved 12,000 lives, and in only thirty-nine instances have they been capsized, while in only twenty-one were lives lost. Of large boats the Institution possesses 23. These have been out 653 times and saved 1,668 lives, without once being turned over. The possibility of using steam has been anxiously considered by the Lifeboat Institution. They experimented as far as was possible for two years in this direction, and a special committee was formed at Liverpool to consider the subject. They came reluctantly to the conclusion that steam could not be used for the purpose.

It is not quite impossible that a suitable engine and propeller could be employed. The difficulty lies in the boiler. It is very difficult to see how a boiler could be fired at all; but even if it could, it is clear that the water and steam would be continually changing places. What, for example, would occur when a boat stood up on end? And without going so far as this, it is plain that no gauge yet made could give the smallest trustworthy evidence as to what was the level of the water in the boiler. The only attempt that could be made at using a boiler would be to hang it in gimbals. Again, the propeller must be at times working in air, then deeply submerged. If placed anywhere outside the hull, it would probably be torn off. If put under her, it must in the nature of things be very inefficient. It is worth notice that neither Mr. Benjamin nor Mr. Taylor thought it worth while to deal with the boiler problem as if it was of any importance. Indeed, their proposed lifeboat, being comparatively a big, heavy craft, would not labor under the same difficulties as an ordinary lifeboat would. The weight of such a boat is about two and a half to three tons. That of four large boats possessed by the Institution is ten tons each. The lifeboat of Messrs. Benjamin and Taylor weighs twenty-seven tons empty. But, as Captain Chetwynd showed, such a large craft would be useless in breakers. The modern lifeboat is a remarkable example of the skillful adaptation of means to an end, and to depart from its type in any way is, to say the least, an extremely doubtful experiment.

There is another difficulty in the way of the adoption of steam at sea which we have not yet considered. It is the grave objection which lies in the way of experimenting with an invention of this kind. Let us suppose that in a heavy gale a steam lifeboat put to sea with a dozen men on board. If the machinery broke down or became inoperative—let us say from excessive priming due to the rapidly changing position of the boiler—the lives of all on board would be lost. No one in authority would take the responsibility of trying so perilous an experiment. It is obvious, however, that before steam lifeboats can be pronounced satisfactory, such an experiment must be made, not once nor twice, but many times. Among inventors, none has had any experience of lifeboat work. It is said that one enthusiastic individual, who believed that he had solved the problem, went out one night with a lifeboat crew to gather experience. Some hours subsequently he found himself on shore, half dead with cold and misery; sorely beaten and bruised and shaken; almost drowned and wholly miserable. When he had recovered, one of his first acts was to tear up his drawings and burn his models. Even with such an experience before them, there are no doubt men who will still invent in this direction, and to such we would tender a word of advice. From any steam engine or other motor dependent on fire, nothing is to be hoped. If it were possible to put a motor on board which would not depend on such aid, it would, no doubt, prove very useful. It is a *sine qua non* that the motor must be of such a kind that it will leave the men as free as they are now to use their oars or sails, so that, should the motor fail, the crew would run no additional risk because of its presence. There is but one scheme which holds out even a faint chance of being practicable, and that is the use of electricity. It would be possible to put storage batteries into a lifeboat, and to so secure them that they would continue to work under any conditions short of turning the boat upside down. The electrical launch shows that such a mode of propulsion is, under certain conditions, possible, and the experiment of using electricity might be tried without much risk of life. But when we have said so much, we are bound to add that nothing has yet been done in electrical marine propulsion which leads us to believe that it can be applied with success to lifeboats. It may be that a steam engine may yet be devised on, say, the Lamm hot water system, which would render the use of a fire in the boat unnecessary; but of this we see, we confess, no hope. However, no one can place a limit to the power of engineers. We have set the broad facts of a most interesting problem before our readers; possibly, they may find its solution.—*The Engineer.*

COMPRESSED AIR FOR LIFEBOATS.

To the Editor of the Scientific American:

You print an article from the *Engineer*, on the means of forcing lifeboats out through the heavy surf and the rough water which are the necessary concomitants of the very circumstances which make their services of vital importance. The difficulties to be overcome are very forcibly and very correctly set forth, and the writer shows conclusively that the use of steam as a driving power for lifeboats is not within the range of possibility. The fire could not be maintained, nor could a boiler of any form, even if hung on gimbals, do its work. The violent shocks, to say nothing of the topsy-turvy commotions which the boat is constantly receiving, preclude absolutely the conjoint presence of steam and boiling water in the same reservoir.

If a lifeboat is to be forced out through the surf in any other way than by means of oars, it must clearly be by some power different from steam. And my present object is to show that such a power we have ready to our hand. It is now coming more and more into use, and for this special service is most admirably adapted; it is *compressed air.* Among several articles written for you by me in 1883, hoping to draw attention to the "Storage of Wind Power," was one, in your paper of Dec. 8, relating to its application to small motors. The facts, and the inferences from them, there stated bring us very appositely to the consideration of this matter of the lifeboats. The motor demanded must be: 1. Compact. 2. Unaffected by position or by shocks. 3. Always ready. 4. Able to supply the full power of a boat's crew and more, for often the strength of the crew is insufficient. 5. Sure in its action, and without risk of failure. 6. Involving as little weight as possible. Every one of these points is perfectly covered by the use of compressed air, as we shall see.

Nos. 1, 2, and 3 we need not consider, for they are manifest. Let us look to the requisite provision for No. 4. I propose to furnish the equivalent of twelve men, though no lifeboat carries such a crew on our coast. Such an amount of power, equal to two nominal horse power, will never be needed for any continued length of time. It is barely, in driving the boat out through the breakers, that it may be required, and for this a very few minutes must always suffice. After this, her crew are equal to her demand. And as the services of a lifeboat, in case of wreck, are limited to a brief period of time, we may safely calculate that the equivalent of one horse power for four hours is all that we need to provide and keep in store, and we can base our calculations on this amount.

Taking the ordinary tables, and assuming that the pressure on starting is 3,000 pounds, we find that reservoirs holding in the aggregate six square feet will give us all we need, with a surplus. After a service of four hours, we shall have in store a pressure of about 1,000 pounds. This is on the reckoning that we turn on as much as four horse power if required for sudden and brief strain. Thirty-one feet of six inch pipe will afford us the space indicated, and, if made of good steel, need not weigh over 300 pounds, say the weight of two men. But we have saved double that amount of load for the boat, for we have diminished the number of her crew. The services of the crew of a lifeboat are chiefly to manage the craft and take her to and from the wreck. Not more than two men commonly, and sometimes only one, can give their attention to the life saving work, all their skill and strength being otherwise demanded. And as we have the power for propulsion independently supplied, the boat need carry men only in proportion.

Another very important point is this: In shipping the terrible seas which so often come on board in the breakers, the men are caught by them at the greatest disadvantage possible. At the very moment when the crashing sea comes down on their heads and backs, each man's utmost strength must be given to his oar, and he is braced as solidly as the timbers of the boat, and receives the heavy blow without the slightest chance to shield himself. If, on the contrary, we are driving the boat as has been here proposed, the men can be shielded very greatly, and many bad injuries avoided.

As to the mode of applying the power secured in the use of compressed air, opinions may be various, as was clearly shown in the article mentioned, where some of the difficulties are well stated. But with the power supplied, we certainly can find the means of using it. My own preference is decidedly for the method recommended by me in your paper of Jan. 5, 1884, that is, direct pneumatic propulsion. It needs perhaps a large amount of experimental work, but I fully believe that for such service as this of the lifeboat it affords the most efficient and most economical method available.

Of the method of compressing the air and holding it ready for instant service, I say nothing here. In the articles to which reference has been made, I expressed my ideas in brief on that point. A.

THE RAISING OF A WRECKED STEAMSHIP.*

THE Peer of the Realm, a screw steamer of 1,813 tons net register, and about 300 ft. length over all, laden with 2,600 tons of coal, ran on the rocks on the east side of Lundy Island during a fog on the 11th of February, 1885. Her position was a dangerous one, being within 30 feet of perpendicular cliffs more than 200 ft. high, where it was impossible to land; the only landing-place on this little island is at the southeast corner, and is approachable only in fine weather. After careful examination of the wreck, although she had been given up as a total loss, the writer was confident, from his experience in the successful raising of several previous wrecks, that she could be profitably raised; and on the 13th of July he was commissioned to undertake the operation, which was carried out according to the following plan.

The after-part of the vessel being double-bottomed throughout its length of 80 ft., the water neither rose nor fell so fast inside as the tide outside. In this part it was considered that the leakage could be kept under by two 8 in. centrifugal pumps, after throwing overboard a large quantity of coal, so as to lighten the vessel, and to form a well from which the windbore of the pumps could draw.

Amidships it was decided to do nothing beyond securing as firmly as possible the bulkheads fore and aft of the space occupied by the engines, boilers, and coal bunkers, and to allow the water in this space to rise to its level.

Throughout the 142 ft. length of the fore part of the vessel, from the boiler-room bulkhead to the stem, it was decided that the coal stowed in the hull must be platformed over, with a timber deck strong enough to serve as a new bottom, and to keep the wreck afloat with the assistance of two 8 in. centrifugal pumps.

For carrying out these operations the steamer Hoy Head was chartered, and on board her were placed four 8 in. centrifugal pumps, with engines and boilers for working them; also the whole of the timber for platforming the fore part of the wreck, and a large quantity of other materials and appliances. Everything was so arranged that what was first wanted was uppermost, and was easily got out by the aid of the steam winches. The Hoy Head was also fitted with the requisite accommodation for the workmen, freshwater tanks, cooking appliances, etc.; she thus served during the whole of the time both as workshop and home for all the men employed on the work.

The tides had to be carefully considered, and every advantage taken of them when at their lowest, inasmuch as very little could be done during neap tides. At the lowest tides there was 12 ft. of the wreck under water at the stem and 21 ft. at the stern, but only for a short time, as the tide falls and rises very rapidly; at high water her masts only were to be seen, the highest high-water line being about 29 ft. above the lowest low-water line. As soon as the rising tide drove the men from the wreck, they occupied themselves on board the Hoy Head in preparing the materials for the next ebb. Whenever easterly winds prevailed, these prevented any work being done upon the wreck; and on some occasions the Hoy Head had to go for refuge to Ilfracombe.

Operations at the wreck were commenced on the 24th of July, 1885, and continued until the 30th, when they had to be suspended on account of bad tides. Work was resumed on the 5th of August, and by the 12th the platforming was completed on the top of the lower stringers in the fore part. With the aid of the steam winches a large quantity of the coal was thrown overboard from the aft part, and some also from the fore part, when the tide was down; and all heavy weights to be placed in the wreck were deposited in almost exactly their intended positions, where they were then quickly made secure.

The platform beams of spruce pine 10 in. square were laid transversely on the top of the coals in the fore part of the hull, being placed 4 ft. apart. Each was in two halves, with a long scarf joint well bolted together. The advantage of this plan was that they were easily handled and got in between the iron stanchions, and fixed in their places more expeditiously. From dimensions taken at low tide, the several pairs of halves were prepared beforehand on board the Hoy Head, away from the wreck, while the tide was up, during which time the men were kept fully employed getting ready the materials for the next ebb. The platform or deck was made of longitudinal planks of spruce pine 11 in. wide by 3 in. thick, nailed down upon the beams and further held down by a transverse plank of the same size laid over them at each beam. Upon this plank were footed the upright timber shores, some of them 10×5 in. and the rest 11×3 in., each firmly fastened at bottom between two chocks of wood nailed to the plank and to the shore; the upper ends of the shores were secrely tongued to the ship's iron beams. About 2 ft. above the center of the upright shores a connecting batten $3 \times 1\frac{1}{2}$ in. ran across the ship, securing all the shores to one another in each athwartship row. The spaces between the iron frames at each side of the ship—most difficult places to make watertight—were each filled with a wooden chock well driven in and calked; and an upright shore was fixed on each of these chocks, with its top end bearing under the deck above, so as to prevent the slightest upward movement of the chock. Over the chocks and round the frames was laid a body of best Portland cement 3 in. thick, which set hard and made a most complete watertight job. In way of the hatches were placed additional transverse beams, for taking the upward pressure of the shores in these places. As the platform had to be fixed so low down in the wreck, there was very little time in each tide for carrying out such a large undertaking; nevertheless, the work was successfully and speedily accomplished, principally through the efficiency of the arrangements adopted as above described, and without the aid of divers for any part of the operations.

After the platform had been calked and finished, the two iron pump-wells were fitted in it, one in each of the two compartments into which the fore part of the ship was divided by an iron bulkhead, and a hole was cut through the bulkhead for allowing each well to get an equal share of water. When all the work had been tested, two 8 in. centrifugal pumps were placed on the main deck, one to draw from each well. So complete was the workmanship found to be, that the pumps were not required to work more than half their time during the tedious voyage of sixteen hours from Lundy Island to Cardiff.

On the morning of the 14th of August it was determined to make the attempt to raise the wreck. With the receding tide, steam was got up in the four-deck boilers. Before break of day the wreck was felt to move slightly with the rising tide, and at 5:45 A.M. she was completely afloat. After another careful examination, all round the tugboats received the signal to tow, and in two minutes she was afloat in deep water, towed by four powerful screw tugs, as well as by the steamer Hoy Head, made fast alongside her. A speed of seven knots per hour was maintained until abreast of Ilfracombe, and then a slower rate up channel to Cardiff, which was safely reached at 10 P.M. All on deck being a complete wreck, with the bulwarks all swept away, the freeboard amidships was only 21 in. in coming up channel. The displacement with this amount of freeboard was 4,780 tons, being the weight of the vessel herself and all she contained, and the displacement up to the deck being 5,180 tons; there was therefore a surplus buoyancy of no more than 400 tons, forming a remarkably small margin for bringing the wreck safely up channel.

After discharging in the following week the remainder of the coal in the after hold, only the wreck was safely docked in one of the city docks of the Mountstewart Shipbuilding, Graving Docks, and Engineering Company, in Cardiff. The hull had become coated with large quantities of barnacles and sea-weed, and these having been cleared off, it was found that her keel, bottom shell-plates, frames, and floorplates were broken in a great number of places for about half her length, affording full scope for the water to flow in and out freely, and thus proving the platforming to be the best method that could have been adopted. On carefully examining the hull after being docked, it was very gratifying to find that, although the wreck had

* Paper read before the Institution of Mechanical Engineers, by Mr. Thomas W. Wailes, of Cardiff.

been exposed to much severe weather, she had not strained a single butt or rivet in her topsides, the whole of the damage to the hull being below the bilges. Her rudder and sternpost being broken and useless, she had to be steered by manipulating the tugs towing her up to Cardiff. The heavy seas rolling over her had completely smashed in the after deck, as also the bridge, and the engine and boiler casings, etc.

In addition to the execution of the necessary repairs, all of which were carried out in conformity with the requirements and under the supervision of Lloyd's and the Board of Trade, the steamer was thoroughly overhauled and remodeled internally. Having been completed under her new name of the Dunbar, she left the graving dock on the 11th of January, 1886, for her trial trip in the Channel, which went off without a hitch, and was in every way satisfactory.

[THE NEW SOUTH.]

THE SHIP RAILWAY.

LETTER FROM J. J. WILLIAMS, C.E.

JACKSON, TENN., January 2, 1886.

Hon. JOHN T. MORGAN, *U. S. Senator:*

Dear Sir: Learning that you had introduced the Tehuantepec Ship Railway Bill in the Senate, and having been employed, in the last thirty years, by four different companies on the surveys of the Isthmus of Tehuantepec—the Garay, or Hargous, the Sloo, the Stevens, and, lastly, by Capt. Eads, and having published a number of reports, including that published in London, giving the results of our trip to Europe in 1871, as one of the commission composed of the late Gen. J. G. Barnard, U. S. Engineers, Julius W. Adams, formerly President of the Society of Civil Engineers, N. Y., and myself, to examine the ship canals and artificial waterways of the Old World, with special reference to the then proposed Tehuantepec ship canal; besides referring you, more particularly, to my report showing the results of the survey for a railroad in 1852, in a book of 295 pages, with a separate one of maps, all of which are to be found in the Congressional Library, in a book entitled the "Isthmus of Tehuantepec," and some of the reasons why I have taken the liberty to address you on the subject.

My report of 1852, which was translated into Spanish, by order of the Mexican Government, gives the result of survey for a railroad across that Isthmus, made under the direction of the late Gen. J. G. Barnard, who, if I am correctly informed, was the only U. S. engineer that stood by Capt. Eads in his jetty improvements at the mouth of the Mississippi River, and who would have stood by him to the last in his ship railway enterprise.

If you examine my report, referred to, in the Congressional Library, you will find what Gen. Barnard says of me, in a letter of his which I published in the preface. Besides, Admiral Davis, in his report upon the different Isthmus routes, says (page 5) that I am the authority for that part of the continent. I mention these things, not from egotism, but simply to show you that what I may say about the ship railway is, perhaps, worthy of some consideration.

On the 19th of March, 1866, nearly twenty years ago, the Senate of the United States passed the following resolution:

Resolved, "That the Secretary of the Navy furnish, through a report of the Superintendent of the National Observatory, the summit levels and distances, by survey, of the various proposed lines for interoceanic canals and railroads between the waters of the Atlantic and Pacific Oceans, as also their relative merits as practicable lines for the construction of a ship canal, and especially as relates to Honduras, Tehuantepec, Nicaragua, Panama, and Atrato."

The great superiority of a ship railway over a ship canal was not understood at that time, but now the fact has been established, beyond question, by some of the most celebrated naval constructors and scientific engineers of both Europe and America.

In compliance with the above resolution, Rear-Admiral Charles A. Davis, the then Superintendent of the National Observatory, made a very elaborate and one of the most complete and reliable reports ever made on the subject of interoceanic canals.

On page 30 of his report, the Admiral gives a table showing the saving in money to the trade of the United States that would result from the use of the Isthmus Canal, according to *Official Statistics* for the year 1867, the total of which is $35,995,930. This is the same result as obtained by F. W. Kelley, a rich merchant of New York, who has already sent three surveying expeditions to the Atrato route, two of them at his own expense, and, perhaps, has no superior in his information about commercial statistics, and especially relating to the commerce that would pass through the Isthmus if the route was open.

Please bear in mind that the above is the result obtained by the Senate's own appointee, upon which all my calculations are based; and, right here, I wish to say that I have as yet seen no argument that can convince me that Admiral Davis and Mr. Kelley are both incorrect in their statements; for had the canal or ship railway been open for the passage of ships half a century ago, it would, in all probability, have averted our war with Mexico, saved us from our own civil war, and thereby thousands of lives and over two thousand millions of dollars, or the entire cost of the Mexican and our own civil war, for the reason that the whole course of events would have been changed, and the minds of our people turned into a different channel, tending toward the "peaceful intercourse of nations," and between the North and South of our own country. This immense loss, together with our loss on commerce, would have footed up an average saving to the United States, if the route had been open half a century ago, of full seventy-five millions per annum.

It would also have revolutionized the whole commerce of the world, and turned the trade of Western Europe through the Gulf of Mexico to the Pacific, right by our very doors, and, as I said in an extract of my report which I mail you to-day (page 28), published in London in 1871, it would have opened the mouth of the Mississippi River to the Pacific Ocean—another world of waters. Consequently, our commerce, besides all the before-mentioned advantages, in this way going West, having 3,000 miles the start over Western Europe in the race for the trade of the Pacific, would be immensely increased, and our people benefited in a thousand ways, and in one, more especially, at the present time, if the route was open, in the sale of locomotives, iron and steel rails, cars, and all kinds of railway supplies to China, where they have recently commenced in earnest the construction of railroads. Now we have more than double that distance, or 6,000 miles, against us in going east round the world to China. We would have saved, in 1866, had the route been open, $35,995,930, the result obtained by Admiral Davis and F. W. Kelley, as before mentioned. In round numbers, $36,000,000, which represents a capital of $600,000,000 at 6 per cent., $720,000,000 at 5 per cent., and $900,000,000 at 4 per cent. As the capital represented is inversely as the rate of interest, one-half of either of these amounts, it would be safe to say, our Government could, *if necessary*, afford to expend in the construction of the ship railway. But the whole guarantee which Capt. Eads asks is not over $37,500,000, which does not attach until after the ship railway is completed and in successful operation.

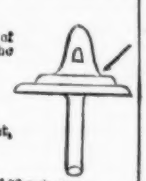
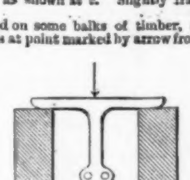
After that it can take care of itself, so that the Government would run no risk under any circumstances, unless the predictions of the most celebrated naval constructors and scientific engineers of both England and America should prove a failure.

But this is not all, as the above calculations are based on what would have been the condition of our trade in the year 1866, had the route been open during the last half century.

On page 31 of his report, the Admiral says that the trade of the United States increased 93 per cent. in the last ten years previous to 1866, and if it increases 100 per cent. in the next ten years, the yearly saving to the United States would be $71,991,860, or, in round numbers, $72,000,000, which represents a capital of $1,200,000,000, one-half of which, or at least $600,000,000, it seems our Government and people would have been justified in expending, *if necessary*, in 1876. All of this shows how very much faster our trade would be increased with an open passage for ships between the two oceans. Even 5 per cent., or one-half of Admiral Davis' yearly ten per cent., increase in our trade for the last twenty years on the $36,000,000 for 1866, had the route been open at that time, would give $72,000,000 for our yearly saving in 1886; and as this amount represents a capital of $1,200,000,000, it again shows that we could now, if necessary, afford to expend $600,000,000 in open-

APPENDIX I.

Details of Tests of Small Steel Castings representing Articles of Common Use in Forged Iron, or Brass Castings, in Ships of War.

Number of Fig.	Article Tested.	Kind of Steel Used.	Description of Test Applied.	Remarks.
1	Clips for water-tight doors	Crucible steel	Bent cold on an anvil by sledge hammers. Not fractured	Very satisfactory.
1a	Ditto	Ditto	Healed and straightened as shown, then cut in two and welded up, and bent double when hot across the weld	Proved to possess good welding properties. Very satisfactory.
2	Eye-plate as used for iron beams, &c.	Crucible steel	The eye bent cold through an angle of 45 deg. by blows from a sledge hammer. No fracture	Very satisfactory
3	Pivot-bar for a 20-pounder gun	Crucible steel	One end of the arc of the bar was placed on an anvil and the other struck by a small steam hammer, it was distorted as shown on the sketch before any fracture took place.	Very satisfactory
			It took four blows of a 22 cwt. weight falling through a height of 4 ft. to fracture the straight part of the pivot-bar	Very satisfactory
4	Clips for securing chains of guns	Crucible steel	Bent on an anvil by a steam hammer, as shown on sketch, without fracture	Very satisfactory.
5	Hooks for tackle blocks	Crucible steel	The hook was placed on an anvil, and the point closed as shown by a steam hammer. No fracture	Very satisfactory.
6	Internal binding for 10 in. snatch block	Crucible steel	The binding was placed in a vice, and opened out by a lever, slight fracture in angle as shown	Very satisfactory.
			Another binding hook and pin were then placed in a testing machine, and tested up to 12.277 tons, when the binding became distorted round the pin, and the hook broke	Hook took a permanent set at 6.071 tons. Very satisfactory. Pins of blocks of wrought steel.
7	Internal binding for 10 in. treble blocks	Crucible steel	The binding was bent on an anvil by a steam hammer, as shown on the sketch. No fracture.	Very satisfactory.
			Another binding hook, &c., were then placed in a testing machine, and tested up to 8.035 tons. Hook fractured	Satisfactory. Pins of blocks of wrought steel.
8	Deck-plate with double eyes and links for securing guns	Crucible steel	This article was placed on a hollow iron bed, and subjected to blows from a falling weight of 22 cwt., viz.: 1st blow, 2 ft. fall Two corners broke off owing to unequal bearing in hollow plate. See Fig. 8 2nd blow .. 2 ft. fall. No further damage. 3rd " .. 2 " " " 4th " .. 6 " " " 5th " .. 10 " " " 6th " .. 22 " " " At the last blow a slight crack was observed in one eye, and one in the middle of plate. See Fig. 8a 7th blow .. .. 22 ft. fall Eyes and links broken. See Fig. 8b	Very satisfactory.
	Link out of a deck-plate as above, 6 in. extreme length, 1.26 in. diameter.	Crucible steel	Elongated .2 in. in the testing machine, and broke at a strain of 27.489 tons	Very satisfactory.
	Fighting pivot for a 64-pr. gun	Crucible steel	Subjected to a test from a falling weight of 22 cwt. in the direction of the arrow, the pivot resting on an iron plate 1st blow .. .. 2 ft. fall 2nd " .. .. 4 " 3rd " .. .. 4 " No damage beyond bending point of pivot, as shown in sketch 	Very satisfactory.
10	Longitudinal intercostal angle 3 in. × 3 in. × $\frac{7}{16}$ in., long 3 ft.	Crucible steel	Subjected to blows from a falling weight of 22 cwt. on the edge A.— 1st blow .. .. 1 ft. fall 2nd " .. .. 2 " 3rd " .. .. 2 " At 3rd blow fractured at a slight fault in edge of casting. See Fig. 10a 	
			Another intercostal was similarly treated 1st blow .. .. 2 ft. fall 2nd " .. .. 2 " Slight fracture on one edge. 3rd blow .. .. .. 2 ft. fall Closed without further damage	Very satisfactory.
			It was then struck on one corner by the same weight 1st blow .. .. 6 ft. fall 2nd " .. .. 10 " Fractured. See Fig. 10b	Very satisfactory.
11	Bedplate for Nordenfelt guns	Crucible steel	This article was placed on a hollow iron casting, the pins resting on the sides of the hollow; it was subjected to blows from a 22 cwt. weight of varying heights, until at 22 ft. the pins were broken off. A second blow at 22 ft. fractured the edge	Very satisfactory.
12	Intercostal beam angle 3 in. × 3 in. × $\frac{3}{8}$ in., long 2 ft.	Crucible steel	This was placed on an anvil under a small steam hammer, and the angle was flattened completely, and the ends distorted as shown on the sketch. Not fractured	Very satisfactory.
13	Intercostal angle 3 in. × 3 in. × $\frac{7}{16}$ in., long 2 ft. 6 in.	Crucible steel	One end rested on an iron plate, and a weight of 22 cwt. was let fall upon the other end 1st blow .. .. 1 ft. fall 2nd " .. .. 2 " Closed 3¼ in. No fracture	Very satisfactory.
			The intercostal was then placed with the edge A on a plate, and a blow was struck at B from a height of 5 ft. See Fig. 13a. No fracture	Very satisfactory.
			Another intercostal was subjected to blows from a steam hammer, the angle being flattened as shown in Fig. 13b. It was then further distorted, as shown at c. Slightly fractured at root of angle	Very satisfactory.
14	Boat's crutch pinnance	Crucible steel	The foot of the crutch was placed on some balks of timber, as shown, and subjected to blows at point marked by arrow from a falling weight of 22 cwt. 1st blow .. .. 8 ft. fall 2nd " .. 12 " 1st blow deflection 1⅛ in. 2nd blow fractured 	Very satisfactory.
			An arm of the crutch was straightened cold by a small hydraulic jack. Not fractured	Very satisfactory.
	Caulking test ..	..	An intercostal angle with one edge chipped was rivetted to a plate, and was caulked with ordinary caulking tools.	Very satisfactory.

Upon trial this steel was found to weld easily. The average tests of samples gave as follows: Tensile test 28.932 tons per square inch. Elongation test in 2 in. 21.25 per cent. Bending test 2 in. × $\frac{3}{8}$ in. 82 deg.

STEEL CASTINGS.

ing the route for ships across the American Isthmus. The above figures, together with what has already been said, will, perhaps, not appear unreasonable when we consider that the construction of only 135 miles of ship railway across the Isthmus of Tehuantepec will connect the Gulf of Mexico with the Pacific Ocean, and unite our Atlantic and Pacific coasts, so as to give the United States as well as the Mexican coastwise commerce of the two oceans the advantage of only 135 miles of ship railway, from Minatillan, at the head of navigation on the Gulf, to Boca Barra, on the Pacific, instead of the enormous distance between the same points of 16,000 statute miles around Cape Horn, thus cutting our continent in two, and causing the benefits to the people of the United States to mount up to thousands of millions of dollars. We have already lost, in the last half century, over two thousand millions, to say nothing of the loss in the previous half century, as I shall presently show.

What has already been said is such an overwhelming argument in favor of our Government aiding the enterprise that it is, perhaps, not necessary to mention the additional millions our commerce would save on the 25 per cent. reduction on our tonnage tolls over the ship railway, in case Congress should pass the ship railway bill. It will certainly be the greatest and most useful wonder of the world.

It is somewhat remarkable that the importance of Admiral Davis' report should have been lost sight of for the last twenty years. More especially as 12,000 copies of it were printed in 1866–67 for distribution by order of the United States Senate. It may have resulted from the little interest which our people generally take in reading over and understanding public documents.

I will now endeavor to show you what the loss to the trade of the United States has suffered in the last half century. For this purpose I will only take 5 per cent., or one-half of Admiral Davis' 10 per cent. increase.

He says the annual saving by the use of the canal, which is our loss without it, for 1866 is $35,995,930, as before mentioned, or say $36,000,000; and at his estimated increase of 10 per cent. per annum, it would double itself in ten years, which makes our annual loss for 1876 $71,991,860, or say $72,000,000; but as I put the increase at only 5 per cent. on the $36,000,000, it will require twenty years to double itself, making our annual loss in 1886 $72,000,000. Equating this amount with 5 per cent., for the last fifty years, gives $20,571,428 as our annual loss in 1836, the beginning of the half century. Taking a mean of the two extremes gives $46,285,714, our average annual loss, which multiplied by fifty years makes the astonishing amount of $2,314,285,700, which our commerce and people have lost in the last half century for the want of an interoceanic canal or ship railway, or, in other words, what we could have saved during that time with an open passage for ships between the two oceans, to say nothing of our loss during the previous half century.

The question now is, Shall this enormous loss to our people be permitted to increase from year to year, or will our Senate and Congress put a stop to it by passing the ship railway bill?

Is there anything before the Senate and House more important than this?

It will immortalize all parties who are instrumental in opening this route.

In conclusion, if I may be permitted to make the suggestion, I would say that it should not become a political or sectional question, as every man, woman, and child in the whole United States and Mexico are more or less interested in its accomplishment.

I have the honor to be, very respectfully, your obedient servant, J. J. WILLIAMS, C.E.

REFRIGERATING AND ICE-MAKING MACHINERY AND APPLIANCES.*

By T. LIGHTFOOT.

THE subject of refrigerating and ice-making machinery has not hitherto, so far as the author is aware, been dealt with in a comprehensive manner by any engineering society. The purpose, therefore, of the present paper is to describe the various systems at present in use, giving also short sketches of their development, together with some considerations respecting their practical application and working, in the hope that this may prove an acceptable contribution to the *Proceedings* of the Institution, and lead to a profitable discussion upon a subject the importance of which is daily becoming more manifest.

The primary function of all refrigerating and ice-making apparatus is to abstract heat, the temperature of the refrigerating agent being of necessity below that of the substance to be cooled. It is obvious, however, that without provision either for rejection of the heat thus abstracted or for renewal of the refrigerating agent, equalization of temperature would ultimately ensue, and the cooling action would cease. In practice, if the machine is to work continuously, one or other of these means must be adopted; and a complete refrigerating machine therefore consists of an apparatus by which heat is abstracted, in combination either with some system for renewing the heat-absorbing agent, or, as is more usually the case, with a contrivance whereby the abstracted heat is rejected, and the agent is restored to a condition in which it can again be employed for cooling purposes. The subject can be conveniently dealt with under the four following heads:

1. Apparatus for abstracting heat by the melting of a solid.
2. Machinery and apparatus for abstracting heat by the evaporation of a more or less volatile liquid.
3. Machinery by which a gas is compressed, partially cooled while under compression, and further cooled by subsequent expansion in the performance of work, the cooled gas being afterward used for abstracting heat.
4. Considerations as to the applications of the various systems.

1.—*Apparatus for Abstracting Heat by the Rapid Melting of a Solid.*

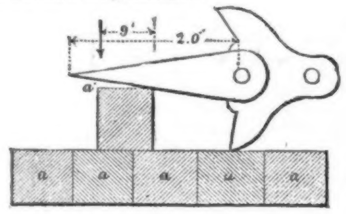
This is probably the oldest method of artificial cooling. When a substance changes its physical state, and passes from the solid to the liquid form, the force of cohesion is overcome by the addition of energy in the form of heat. The effect may be produced without change in sensible temperature, if the heat be absorbed at the same rate as it is supplied from without. Thus, as is well known, the temperature of melting ice remains constant at 32° Fah.; and any increase or decrease in the heat supplied merely hastens or retards the rate of melting, without affecting the temperature. Mixtures of certain salts with water or acids, and of some salts with ice, which form liquids whose freezing points are below the original temperatures of the mixtures, do not, however, behave in this way; for under ordinary circumstances the tendency to pass into the liquid form is so strong, that heat is absorbed at a greater rate than it can be supplied from without. The store of heat of the melting substances themselves is therefore drawn upon, and the temperature consequently falls until a balance is set up between the rate of melting and the rate at which heat is supplied from outside. This is what takes place with ordinary freezing mixtures. The amount of the depression in temperature appears to depend to some extent on the state of hydration of the salt and the percentage of it in the mixture. Almost the only salts used are those of certain alkalies, few others possessing the requisite solubility at low temperatures. A list of the freezing mixtures usually employed is given in the appended table I.

Such a method of abstracting heat is extremely convenient for the laboratory and for some other special purposes. Attempts have also been made to apply it commercially on a large scale for the manufacture of ice and for cooling. The late Sir William Siemens constructed an ice-making apparatus in which calcium chloride was employed. The reduction in temperature produced by this salt in water is about 30° Fah.; but as this was not sufficient for freezing when the initial temperature of the water was about 60° or 65° Fah., a heat interchanger was introduced, by means of which the spent liquor at about 30° was utilized for cooling the water before it was mixed with the salt; and to the extent of this cooling the degree of cold produced was intensified. The salt was recovered by evaporation, and used over again. Although this apparatus worked well and produced ice, the inventor himself considered the process inferior to mechanical methods, and abandoned it. In the Toselli machine, a mixture of ammonia nitrate and water is used, by means of which a reduction in temperature of about 40° Fah. is obtained. The apparatus consists of a vessel in which the solution of the salt is effected, and an ice can containing several slightly tapering moulds of circular cross section and of varying sizes. The moulds, being filled with water, are intro-

* A paper read before the Institution of Mechanical Engineers, May, 1886.

APPENDIX II.

A Statement of some of the Large Steel Castings which have been Made, and Tested under various Conditions, at various Works, distinguishing in each Case the Description of Steel Used and the Tests Applied.

Number of Fig.	Casting.	Kind of Steel Used.	Description of Tests Applied.	Remarks.
2.	Stem for a foreign war vessel	Open-hearth steel	Falling test through 60 deg., *i.e.*, the upper end of each piece of stem was raised, while the lower end rested on the ground, until the side of the stem above made an angle of 60 deg. with the ground; it was then let fall The casting was then slung, and sounded with hammers	Examined and found perfectly sound. Satisfactory.
3.	Stem for a foreign war vessel, with under-water torpedo tube	Open-hearth steel	This casting was not subjected to a drop test Test pieces gave the following results: Tensile per sq. in., 36 tons Elongation in 8 in., 12.5 per cent. Bent, cold, 1¾ in. × ¾ ft. – 42 deg.	
4.	Stern-post for a foreign war vessel	Open-hearth steel	Each piece was raised bodily 10 ft. and allowed to drop on hard ground Afterwards slung, and sounded with hammers Test pieces gave the following results: Tensile per sq. in., 31 tons Elongation in 8 in., 20 per cent. Cold bend, 60 deg.	Results satisfactory. Very satisfactory.
5.	Stern-post for H.M.S. Forth	Crucible steel	1. The keel piece Z Y resting on the ground, the upper part was raised to an angle of 60 deg., and then let fall 2. The points X Y resting on the ground, the post was lifted at Z to an angle of 60 deg., and then let fall The casting was then slung, and sounded with hammers Sample tested: Tensile per sq. in., 30.5 tons Elongation in 6 in., 12.5 per cent. Bent cold, .735 in. in diameter to an angle of 98 deg.	Very satisfactory.
6.	Balanced solid rudder for a foreign war vessel	Crucible steel	Test pieces: Tensile per sq. in., 30.61 tons Elongation in 8 in., 13.67 per cent.	
7.	Stern frame and solid rudder, for a merchant vessel	Crucible steel	Tensile per sq. in. 31.09 tons 33 8 " 32.00 " Elongation in 3 in. 28.5 per cent. 23.95 " 15.18 " Bent cold 1¼ in. × 1¼ in. through an angle of 122 deg. before breaking	Satisfactory.
8.	Brackets for supporting after ends of propeller shafts for H.M.S. Benbow.	Crucible	Falling test: Raised to an angle of 60 deg.— 1. With ends of arms on ground, boss raised 2. With one arm on the ground, the other raised 3. The opposite to 2nd. And from these positions allowed to fall on the ground Slung, and sounded with hammers. No defects Test pieces: Tensile per square inch { 25.507 tons, 26.065 ", 27 681 ", 26.746 " Elongation per cent. in.: 8 in. .. .. 15.63 8 " .. .. 24.21 6 " .. .. 19.79 6 " .. .. 16.66 Bent cold: .75 in. in diameter .. .. 130 deg. 1 " × 1 in. .. .. 85 " 1 " × 1 " .. .. 140 " 1 " × 1 " .. .. 140 "	Satisfactory. Satisfactory.
9.	Anchor weighing 10 cwt.	Special steel	One arm A was let fall from a height upon rigid steel slabs First fall, 10 ft. No damage Second fall, 17 ft. No damage Then placed thus: *a a a a* and *a*[1] being steel ingots 	Results very satisfactory.
10.	Saddle for gun-carriage	Open hearth steel	Tensile per square inch 28.81 tons " " 19.2 " Elongation in 2 in., 24 per cent. " " 20 "	
11.	Main bearing frame for marine engine	Open hearth steel	Not any tests applied.	
12.	Crown wheel	Steel made by special process	Let fall from a height of 12 ft. upon hard ground. No damage Test-piece from worm and crown wheels gave— Tensile per square inch .. .. .. 37.988 tons Elongation in 4 in. .. .. 10.94 per cent.	Satisfactory.
13.	Deck-plate	Steel made by special process	Falling test as for worm and crown wheels. No damage Test pieces gave: Tensile per square inch .. .. .. 27.50 tons Elongation in 2 in... .. .. .. 6.20 per cent.	This was a very severe test, but the casting stood it well. Very satisfactory.
14.	Capstan body found unfit for H.M.'s service, owing to defects in casting	Steel made by special process	This was let fall from a height of 12 ft. upon hard ground. No damage The first capstan body cast was found to be defective when taken out of the sand. This the Committee were allowed to test in any way they thought proper 1. It was let fall from a height of 16 ft. upon hard ground. No damage 2. It was let fall from a height of 10 ft. upon a bed of steel ingots, when the flange was fractured in the place where the defect was observed and for which it was condemned —It was again let fall upon the steel bed from a height of 15 ft. 6 in., when a portion of the flange was broken off Tested in machine: Tensile, per inch .. .. .. 26.526 Elongation in 2 in. .. .. .. 6.250 per cent.	Very satisfactory. Very good result for such an intricate casting, and with known defects.
	Bar or drumhead	Steel made by special process	Let fall from a height of 12 ft. upon hard ground. No damage. Test pieces: Tensile per square inch .. .. .. 30.00 tons Elongation in ¾ in. .. .. .. 12.5 per cent.	Satisfactory.

STEEL CASTINGS.

APPENDIX III.

A List of such Articles or Parts of Ship, or her Fittings, which could be advantageously made of Cast Steel, together with the Tests it is proposed to apply to each.

Number.	Article.	Description of Test proposed to be Applied.			
		Minimum Tensile per Square Inch.	Minimum Elongation in 8 in.	Minimum Bending Cold, 1 in. in diameter, or a Rectangular Section as near to this Area as possible.	Percussive Test of the Article itself.
		tons	per cent.	deg.	
1	Stems	26	10	45	Let fall bodily from a height of 12 ft. upon hard ground.
2	Stern-posts				
3	Rudder-frames	26	10	45	Ditto.
4	Tillers and side rods for steering	26	10	45	Ditto.
5	Paul plates and hoops for rudders	26	10	45	Ditto.
6	Hawse pipes and deck pipes	26	10	45	Ditto.
7	Riding-bitts	26	10	45	Ditto.
8	Capstan	26	10	45	Ditto.
9	Cable compressor	26	10	45	Ditto.
10	Brackets for supporting after ends of screw shafts	26	10	45	Ditto.
11	Anchors	26	10	45	12 ft. fall on an iron slab, and to be tested 25 per cent. above the proof strain for iron anchors.
12	Wheels of various kinds	30	5	20	Fall from a height of 12 ft. on hard ground.
13	Rollers for turrets	..	Special test as at present to obtain crushing strain.		
14	Guard stanchions for bridges, &c.	26	10	50	To fall on an iron slab from a height of 10 ft.
15	Pump stanchions and sockets	26	10	50	Ditto.
16	Racers clip, and other, for guns	26	10	50	The percussive test for clip racers as used in Her Majesty's service to be retained, or to be subjected to hydraulic pressure at all points of its circumference.
17	Gun pivots	26	10	50	To fall upon an iron slab from a height of 10 ft.
18	Cylinders for mounting machine guns	26	10	50	" on hard ground from a height of 12 ft.
19	Racers and clips to Medway mounting for Nordenfelt guns	26	10	50	Ditto.
20	Trollies for Gardner and Nordenfelt guns	26	10	50	Ditto.
21	Tongs, water and bevel, for torpedoes	26	10	50	Ditto.
22	Bedplate for Nordenfelt guns	26	10	50	Ditto.
23	Pivot bars for guns	26	10	50	Ditto.
24	Deck-plate with double eyes and links for securing guns	26	10	50	Let fall on an iron slab from a height of 10 ft.
25	Clip for securing chains of guns	26	10	50	Ditto.
26	Drop bolts for guns	26	10	50	Ditto.
27	Racks and pinions for turning turrets	26	10	50	With the ends resting on hard ground, the racks should be let fall from an upright position. Pinion should be dropped from a height of 12 ft. upon hard ground.
28	Nippers for testing wire rope	26	10	50	Let fall from a height of 10 ft. upon hard ground.
29	Frames for water-tight doors	26	10	50	One end rest on an iron slab, the frame raised upright, let fall from this position on to the slab.
30	Racks and pinions for sliding water-tight doors	26	10	50	Let fall upon hard ground from a height of 10 ft.
31	Cogwheels, &c., and rollers for water-tight doors	26	10	50	Ditto.
32	Clips and handles for water-tight doors, manhole covers, scuttles, &c.	26	10	50	Ditto.
33	Hinges for water-tight doors, scuttles, &c.	26	10	50	Ditto
34	Sheaves and cogwheels for steering gear	26	10	50	Let fall from a height of 12 ft. upon hard ground.
35	Belaying cleats on plates, and belaying pins	26	10	50	Let fall from a height of 10 ft. upon an iron slab.
36	Eye-plates for beams for compressor falls, &c.	26	10	50	Ditto.
37	Studs for lumber irons in iron beams	26	10	50	Ditto.
38	Awning stanchions	26	10	50	Ditto.
39	Sockets for stanchions, awning, &c.	26	10	50	Ditto.
40	Levers and sockets for opening side scuttles	26	10	50	Ditto.
41	Collapsing screw for rigging, guard chains, &c.	26	10	50	Ditto.
42	Internal bindings for all description of blocks	26	10	50	Ditto.
43	Boats' crutches	26	10	50	Let fall from a height of 12 ft. upon hard ground.
44	Intercostal angles for longitudinals, beams, water-tight work, &c.	26	10	50	Let fall from a height of 10 ft. upon an iron slab.
45	Blocks, large, for torpedo derricks, cat blocks, &c.	26	10	50	Ditto.
46	Solid ends for heads, and heels of pillars to beams	26	10	50	Ditto.
47	Shoes for pillars to beams	26	10	50	Ditto.
48	Tulips for ends of torpedo booms	26	10	50	Ditto.
49	Sockets and eyes for ship side and eye hoops for torpedo booms	26	10	50	Ditto.
50	Caps for masts and bowsprits	26	10	50	Ditto.
51	Tulips and steps for masts	26	10	50	12 ft. fall upon hard ground.
52	Stopper bolt for chain cables	26	10	50	10 ft. fall upon an iron slab.
53	Brackets of various sizes and descriptions for stowing gear	26	10	50	12 ft. fall upon hard ground.

As it may be necessary occasionally to repair some of the articles previously named, it is desirable that all the steel used should be capable of being welded.

MEMO.—The foregoing is not intended to be a complete list of the fittings which could be made in cast steel, but rather as a guide to the description of articles which could be made at once; this list could be added to after a trial of the articles named.

Some important articles, such as crankshafts, propellers, framing for engines, &c., are now to some extent being made in cast steel, and the trials of these will probably greatly extend the use of cast steel in this direction."

STEEL CASTINGS.

duced into the freezing mixture; and in a few minutes ice is formed round the edges to the thickness of nearly an eighth of an inch. The rings or tubes of ice are then removed and placed one within the other, so forming a small stick of ice.

Ammonium nitrate is also employed in a machine recently brought out in the United States for the production of ice on a large scale. In one form of this apparatus, intended chiefly for domestic purposes, a series of annular vessels, one within the other, is used; the moulds in which the ice is to be formed being placed in the center. The reduction of temperature produced by the freezing mixture in the outermost vessel cools the water in the second, and this, on salt being added, cools the third, and so on. In this way the cold is very much intensified at the center, and a low temperature can be produced independent of the initial temperature of the water. The number of rings employed varies according to the effect to be produced and the conditions under which the apparatus is applied. The annular vessels together with the ice moulds are carried in a wood casing supported on bearings, the only motive power required being that necessary to rotate the vessels slowly, so as to promote the solution of the salt. Another form of apparatus, designed for continuous use on a large scale, consists of a vessel into which ammonium nitrate is automatically fed, and in which it enters into solution with water previously cooled in an interchanger by the spent liquor, after the latter has left the ice-making tanks or cooling rooms. The cold brine thus produced is circulated by a pump through the ice tanks, or through pipes placed in the rooms it is desired to cool; and is returned through the interchanger to an evaporating tank, where by means of heat the water is driven off and the salt recovered. This is practically Sir William Siemens' apparatus in a somewhat extended form. The cost of producing 15 tons of ice per twenty-four hours with such an apparatus of suitable capacity is stated at 7s. per ton, with good coals at 15s. a ton, and exclusive of depreciation and repairs. This, however, is probably much too low an estimate, being based upon the erroneous assumption that 1 lb. of coal is capable of evaporating 20 lb. of water. Nearly the whole of the coal is used for evaporating the water in recovering the salt, the quantity being given at 2½ tons of coal for every 15 tons of ice. If, however, this has been calculated on an evaporative duty of 20 lb. of water per lb. of coal, the amount actually used will probably be about 5 tons of coal, which would make the cost per ton of ice 9s. 3d. instead of 7s. On the other hand, it must be remembered that under certain climatic conditions much of the water could be evaporated in the open air, without the use of fuel; in which case the coal consumption, and therefore the cost of ice production, would be greatly lessened.

2. *Machinery and Apparatus for Abstracting Heat by the Evaporation of a More or Less Volatile Liquid.*

When a liquid changes its physical condition, and assumes the state of vapor, heat is absorbed in increasing the energy of the molecules. This heat is absorbed without change in sensible temperature; and the amount thus disposed of is usually called the latent heat of vaporization. For different liquids different quantities of heat are required; and for the same liquid the amount varies somewhat according to the pressure at which vaporization occurs. Other things being equal, the liquid with the highest latent heat will be the best refrigerant, because for a given abstraction of heat the least weight of liquid will be required, and therefore the power expended in working the machine will be the least. The principal systems in which the evaporation of liquids is employed may be treated under the following subdivisions:

A. Apparatus in which the refrigerating agent is rejected along with the heat it has acquired.

B. Machines in which heat only is rejected, the refrigerating agent being restored to its original physical condition by means of mechanical compression and by cooling when under compression.

C. Apparatus in which heat only is rejected, by allowing the refrigerating agent to change its physical condition by entering into solution with a liquid, from which it is afterward separated by evaporation and recovered.

D. Machinery and apparatus in which heat only is rejected, by changing the physical state of the refrigerating agent by a combination of both mechanical compression and solution, with cooling.

System A.—This is generally known as the vacuum process, for as the refrigerating agent itself is rejected, the only agent of a sufficiently inexpensive character to be employed is water, and this, owing to its high boiling-point, requires the maintenance of a high degree of vacuum in order to produce ebullition at the proper temperature. The vapor tensions of water at temperatures up to boiling-point at atmospheric pressure are given in the appended table II., from which it will be seen that at 32° Fah. the tension is only 0·089 lb. per square inch. In ice-making, therefore, a degree of vacuum must be maintained at least as high as this. The earliest machine of this kind appears to have been made in 1755 by Dr. Cullen, who produced the vacuum by means of an air-pump. In 1810 Leslie, combining with the air-pump a vessel containing strong sulphuric acid, for absorbing the vapor from the air drawn over, and so assisting the pump, succeeded in producing an apparatus by means of which 1 to 1½ lb. of ice could be made in a single operation. Vallance and Kingsford followed later, but without practical results; and Carré many years afterward embodied the same principle in a machine for cooling and for making small quantities of ice, chiefly for domestic purposes. His machine, which is still sometimes used, consists of a small vertical vacuum-pump worked by hand, either by a lever or by a crank, which exhausts the air from the carafe or decanter containing the water or liquid to be frozen or cooled. Between the pump and the water vessel is a lead cylinder, three-quarters full of sulphuric acid, over which the air, and with it the vapor given off from the liquid, is caused to pass on its way to the pump. The vacuum thus produced causes a rapid evaporation, which quickly lowers the temperature of the water; and if the action is prolonged for about four or five minutes, the water becomes frozen into a block of porous opaque ice. The charge of acid is about 4½ pints, and it is said that from 50 to 60 carafes of about a pint each can be frozen with one charge. So long as the joints are all tight, and the pump is in good order, this apparatus works well; but in practice it has been found troublesome and unreliable, and consequently has never come into anything like general use.

In 1878 Franz Windhausen, of Berlin, brought out a compound vacuum-pump for producing ice direct from water, on a large scale, without the employment of sulphuric acid; and also an arrangement in which sulphuric acid could be used, the acid being cooled by water during its absorption of the vapor, and afterward concentrated, so that a fresh supply was rendered unnecessary. This apparatus was improved on in 1880; and in 1881 a machine nominally capable of producing 15 tons of ice per twenty-four hours was put to work experimentally at the Aylesbury Dairy at Bayswater, being afterward removed to Lillie Bridge, where the author believes it now is. The installation was fully described and illustrated by Carl Pieper in a paper read before the Society of Engineers in November, 1882, and by Dr. John Hopkinson at the Society of Arts about the same time.* It consists of six slightly tapered ice-forming vessels of cast iron, of circular cross section, closed at their bottom ends by hinged doors with air tight joints, into which water is allowed to flow at a regular speed through suitable nozzles, the cylinders being steam jacketed in order to allow the ice to be readily discharged. The upper parts of these vessels communicate with the pump through a long horizontal iron vessel of circular section containing sulphuric acid, which, when the machine is in operation, is kept in continual agitation by means of revolving arms. The acid vessel is surrounded with cold water, which carries off most of the heat liberated during the absorption of the vapor. The pump has two cylinders, one double acting of large size, and a smaller single acting one. The capacities of these cylinders per revolution are as 62 to 1. The air and whatever vapor has passed the acid are drawn into the large pump, which partially compresses and delivers them into a condenser. Here part of the vapor is condensed by the action of cold water, the remainder passing along with the air to the second pump, where they are compressed up to atmospheric tension and discharged. The advantage gained by the use of a compound pump is due to the action of the intermediate condenser and to the compression being performed in two stages, by which the losses from the clearance spaces in the large pump are rendered much less than they would be if compression to atmospheric pressure were accomplished in a single operation. The effect of the pump is said to be such that a vacuum of half a millimeter of mercury, or about 0·0097 lb. per square inch, can be continuously maintained; though in actual work about 2½ millimeters, or 0·0484 lb. per square inch, is as low as is necessary. The concentration of the acid is effected in a lead-lined vessel, in which is a coil of lead piping heated by steam, the pressure in the vessel being kept down by means of an ordinary air pump. No acid pump is needed, as the transfer from one vessel to another is effected by the pressure of the atmosphere. The comparatively cool weak acid on its way to the concentrator is heated in an interchanger by the strong acid returning from the concentrator. Six blocks of ice, each weighing about 560 lb., are formed in about twenty minutes after starting. The charge of acid is said to serve for three makings of ice, after which it becomes too weak, and requires to be concentrated.

The water being admitted into the ice-forming vessels in fine streams offers a large surface for evaporation, and is almost immediately converted into small

* *Transactions of the Society of Engineers*, 1882, page 145; *Journal of the Society of Arts*, 1882, vol. xxxi., page 30.

globules of ice, which fall to the bottom and become cemented together by the freezing of a certain quantity of water that collects there. This water being in a violent state of ebullition, the ice so formed is not solid, but contains spaces or blow-holes, which, as soon as the block is discharged from the vessel, become filled with air and cause opacity. Several attempts have been made to produce transparent ice by the direct vacuum process, but so far without success. Distilled water, or water deprived of air, has been tried, and hydraulic pressure has been used for compressing the porous opaque blocks, but neither plan has been found practicable commercially. It would appear indeed that the only way to make clear ice by the vacuum process is by forming it in moulds, subjected externally to the action of brine previously cooled by the evaporation of a portion of its water. The cost in this case would necessarily be greater; but the ice would be solid and transparent, and would consequently have a higher commercial value. The latent heat of liquefaction of water being 142·6° Fah., the total heat to be abstracted in order to produce 1 ton of ice from 1 ton of water at 60° Fah. is 382,144 Fah. lb. units. Taking the latent heat of vaporization of water at 32° Fah. to be 1091·7, it is obvious that 350 lb. must be evaporated to make the ton of ice. But in addition the sensible heat of evaporated water, which entering at 60° would leave at about 32°, would have to be taken off; and this would require the evaporation of about 9¼ lb. more, making a total of about 360 lb., without allowance for loss by heat entering from without, which would be considerable. The total water actually used is given by Mr. Pieper at 12 tons per ton of ice, including the quantity required for cooling purposes. The fuel consumption is stated to be 180 lb. of coal per ton of ice; but the author understands a much larger quantity is actually required. It is consumed in generating steam for driving the vacuum-pump and the concentrator air-pump, and for evaporating the water absorbed by the acid. According to Dr. Hopkinson, the cost of making 1 ton of opaque ice is 4s.; but the author believes experience has shown that a much higher figure is required to cover the necessary expenses for repairs and maintenance, which in some parts of the apparatus are very heavy. Windhausen's machine has not met with any extended application in this country, owing no doubt to the opaque and porous condition of the ice produced by it and to the large and cumbrous nature of the plant, which must doubtless require great care and supervision in working.

A vacuum apparatus for refrigerating liquids by their own partial evaporation, and for making ice, was brought out in 1878 by James Harrison. Its chief feature is the revolving cylinder or pump, which affords a simple and efficient means of exhausting large volumes of vapor of low tension, without incurring the loss from friction of ordinary piston-packings, and the trouble of keeping them tight and in good working order, while at the same time the first cost is much reduced. The pump consists of a hollow iron cylinder, revolving on a horizontal axis, and divided into compartments by longitudinal partitions of L section. It is partially filled with a non-evaporable liquid, or one which evaporates only at a temperature considerably in excess of that at which the refrigerating liquid is evaporated, and which is also chemically neutral to the vapor that is brought in contact with it. In practice, oil is the liquid used. The refrigerating or ice-making vessels, of any convenient form, are connected by a pipe with one end of a fixed hollow axle on which the cylinder revolves; and inside the cylinder another pipe rises up above the level of the liquid, the longitudinal partitions being stopped short at one end to enable this to be done. The compartments move round mouth downward, carrying with them the vapor with which they are charged, and compressing it to an extent measured by the distance they dip below the surface of the liquid; until, when the lowest position is approached, the compressed vapor is liberated, and rises into a fixed hood near the center, in communication with a second hollow axle at the opposite end of the cylinder to that at which the vapor enters. Through this second axle the compressed vapor passes to a surface evaporative condenser, in which it is partly condensed by the combined action of direct cooling and the partial evaporation of water trickling over the surface; the water of condensation, together with any air, is then compressed to the tension of the atmosphere by a small pump, and discharged. By this process, the author is informed, it is expected to produce opaque ice on a large scale at a cost of about 1s. per ton. The fuel consumption will certainly be very small, because friction, which is a large item in the Windhausen apparatus, is here to a large extent eliminated. There would also be a saving of all the fuel used in concentrating the acid, and of much of the water required for cooling purposes, besides a reduction in the first cost of the plant and in the expense of maintenance.

System B.—This is known as the compression process, and is used with liquids whose vapors condense under pressure at ordinary temperatures. Although, prior to 1834, several suggestions had been made with regard to the production of ice and the cooling of liquids by the evaporation of a more volatile liquid than water, the author believes that the first machine really constructed and put to work was made by John Hague in that year, from the designs of Jacob Perkins. According to Sir Frederick Bramwell,* the liquid used was one arising from the destructive distillation of caoutchouc. The machine, so far as the author is aware, was never put to work outside of the factory where it was constructed. The water to be frozen was placed in a jacketed copper pan, the jacket being partially filled with the volatile liquid, and carefully protected on the outside with a covering of non-conducting material. A pump drew off the vapor from the jacket, and delivered it compressed into a worm, around which cooling water was circulated, the pressure being such as to cause liquefaction. The liquid collected at the bottom of the worm, and returned to the jacket through a pipe, to be again evaporated. This apparatus, though in some respects crude, is yet the parent of all compression machines used at the present time, the only improvements made since the year 1854 having been in matters of constructive detail. The next advance was made in 1856 and 1857 by James Harrison, who brought out a machine embodying the same principles as that of Perkins, but worked out on a larger and more practical scale. It was taken up by the late Mr. Siebe, and was the first ice-making machine that really came into practical use in this country and was employed on a commercial scale. An improved apparatus of this kind, in which ether is used as the refrigerating agent, is still manufactured by Messrs. Siebe, Gorman & Co. The vapor tensions of ether are given in the appended table II. It was not a very volatile liquid, of specific gravity 0·720, having a latent heat of evaporization of 165°, and a specific gravity of vapor of 2·24 compared with air. Its boiling-point at atmospheric pressure is 96° Fah. Messrs. Siebe, Gorman & Co.'s machine, applied to the manufacture of clear ice, consists of a refrigerator, a water-jacketed pump driven by a surface-condensing steam-engine, an ether condenser, and ice-making tanks containing copper moulds, around which brine cooled to a low temperature in the refrigerator is circulated by a pump. The refrigerator is a cylindrical vessel of sheet copper, containing clusters of horizontal solid-drawn copper tubes, through which the brine successively circulates. The shell is connected with the pump by a pipe, the liquid ether from the condenser being admitted through a small pipe having a cock, which is so adjusted as to pass the precise weight of ether that the pump will draw off. What this weight is depends entirely on the pressure at which evaporation occurs; the greater the density of the vapor, the greater is the weight drawn off at each revolution of the pump. The pressure at which evaporation occurs is defined by the temperature to which it is desired to reduce the brine, the boiling point of the ether being regulated so as to give the required reduction of temperature and no more, otherwise the apparatus would not work up to its full capacity. The condenser consists of a cluster of solid-drawn copper tubes placed horizontally in a wood tank, through which cooling water is circulated, the amount of water required in this country being about 150 gallons per hour for every ton of ice made per twenty-four hours. With the temperature of cooling water available in this country, liquefaction generally occurs at a pressure of about 3 lb. per square inch above the atmosphere; but in a warm climate the pressure needed may reach as much as 10 or even 12 lb.

In another apparatus, the ice is made in cans or moulds. The moulds, of sheet copper or steel, are filled with the water to be frozen, and are suspended in a tank, through which is kept up a circulation of cold brine from the refrigerator. As soon as the ice is formed, the moulds are removed and dipped for a few minutes in warm water to loosen the ice, which is then turned out. The sizes of the moulds vary a good deal, according to the capacity of the machine and the purpose for which the ice is to be used. A common plan is to commence with a thickness of 3 inches for a production of 1 ton per twenty-four hours, and to go up to 9 inches for ten tons and upward. The thickness exercises an important bearing upon the number of moulds to be employed for any given output; for, while a 3 inch block can be frozen in eight hours, one 9 inches thick will take about 36 hours. The time, however, varies also according to the temperature at which the brine is worked. For an ether machine, such as that just described, the brine temperature may be taken at from 10° to 15° Fah. Another method is that known as the cell system. This consists of series of cellular walls of wrought or cast iron, placed from 12 to 16 inches apart, the space between each pair of walls being filled with the water to be frozen. The cooled brine circulates through the cells, the ice gradually forming outside, and increasing in thickness until the two opposite layers meet and join together. If thinner blocks are required, freezing may be stopped at any time, and the ice removed. In order to detach the ice from the walls, it may either be left for a time after the circulation of the brine has been stopped, or a better and quicker plan is to pass some warmer brine through the cells. In order to produce transparent ice, it is necessary that the water should be agitated during freezing, so as to allow the escape of the air set free. When moulds are used, this is generally done by means of arms having a vertical or horizontal movement, which are either pushed up by the ice as it forms, leaving the block solid, or work backward and forward in the center of the mould, dividing the block vertically into two equal pieces. With cells, agitation is generally effected from the bottom by means of paddles. The ice which forms first on the sides of the moulds or cells is generally transparent enough even without agitation. The opacity gradually increases toward the center, where the two layers meet and join together; agitation is therefore more necessary toward the end of the freezing process than at the beginning. As the quantity of air held in solution by water decreases as its temperature is raised, it is obvious that less agitation will be required in hot than in temperate climates; for this reason, in India and elsewhere agitation is frequently dispensed with altogether.

Machines using ether as the refrigerating medium are also largely made by Messrs. Siddeley & Co., of Liverpool, and Messrs. West & Co., of Southwark; but they present no special features which are not embodied in the apparatus already described, the points of difference being in details to which it is not necessary to refer. As already stated, the working pressure in the refrigerator must depend upon the extent of the reduction in temperature desired, bearing in mind that, the higher the pressure, the greater will be the work that can be got out of any given capacity of pump. The liquefying pressure in the condenser depends on the temperature of the cooling water and on the quantity that is passed through in relation to the quantity of heat carried away; and this pressure determines the mechanical work to be expended. In any given machine the work may be accounted for as follows:

Friction.

Heat rejected during compression.

Heat acquired by the refrigerating agent in passing through the pump.

Work expended in discharging the compressed vapor from the pump.

Against which must be set—

Work done by the vapor entering the pump.

Assuming that vapor alone enters the pump, the heat rejected in the condenser is—

Heat of vaporization acquired in the refrigerator, with the correction necessary for difference in pressure.

Heat acquired in the pump, less the amount due to the difference between the temperature at which liquefaction occurs and that at which the vapor entered the pump.

Though circumstances vary so much that no absolutely definite statement can be made as to the working of ether machines in general, the following particulars, taken from actual experiment in this country, will serve to show what may be expected under ordinary conditions:

Production of ice, tons per twenty-four hours	15 tons.
Production of ice, lb. per hour	1,400 lb.
Heat-units per hour abstracted in ice-making	245,000 units.
Indicated horse power in steam cylinder, excluding that required for circulating the cooling water and for working cranes, etc	83 I. h. p.
Indicated horse-power in ether pump	46½ I. h. p.
Thermal equivalent of work in ether pump, units per hour	119,261 units.
Ratio of work in pump to work in ice-making	1 to 2·05.
Temperature of water entering condenser	52° Fah.

Assuming the coal consumption per indicated horse power to be 2 lb. per hour, and the price of coal 15s. a ton, the total cost of producing transparent block ice in this country on the ether system with such a machine as that just referred to may be taken at about 5s. per ton, excluding allowance for repairs and depreciation. The production of ice would be about 8·3 tons per ton of coal. For cooling water and other liquids, another machine is used; but in this case the ice boxes are dispensed with, the liquid being passed direct through the refrigerator without the employment of brine. Methylic ether, a liquid with a latent heat of vaporization of —, and which boils under atmospheric pressure at 10·5° below zero Fah., has been employed by Tellier in machinery of practically similar design to that used with ordinary ether. Tellier's apparatus has never come into use in this country, and need not be further dwelt on; for beyond the difference in size of pump, and the obvious alterations due to the higher working pressures, it presents no features of importance. Some years ago Raoul Pictet, of Geneva, successfully introduced sulphur dioxide as a refrigerating agent, and in France a large number of his machines have been made and put to work. In this country also they have been used, but to a much smaller extent. It is a liquid with a latent heat of vaporization of 182°, and under atmospheric pressure boils at 14° Fah. This machine is also of similar design to those in which ether is employed; but Pictet combined the refrigerator with the ice-making tanks, the brine being circulated by means of a fan. In this way the space occupied was reduced, and the efficiency somewhat increased. The cost of producing ice by the Tellier and Pictet machines may be taken at practically the same as that by the other process. Some of the more volatile derivatives of coal tar have been used in compression machines, especially in the United States; but it will be unnecessary to refer to them in detail, as their application has been exceedingly limited.

Anhydrous ammonia, which may now be obtained as an article of commerce, has of late years been very largely introduced as a refrigerating agent, more especially in Germany and in the United States. Under atmospheric pressure anhydrous liquid ammonia boils at 37·30° below zero Fah., and under this condition its latent heat of vaporization is 900°. So far as the cycle of operation is concerned, it is precisely the same as for ether; the liquid is vaporized in the refrigerator by the action of the pump, which then compresses the vapor, and delivers it into the condenser at such pressure as to cause it to liquefy. In the construction of ammonia machines, however, there are two essential points of difference. For, in the first place, the pressure of the ammonia vapor is much higher than that of ether at the same temperatures, its tension at 60° Fah. being 108 lb. per square inch; and, secondly, owing to the action of ammonia on copper, no brass or gun metal can be used in any part with which the gas or liquid comes into contact. One of the chief difficulties encountered in the compression of ammonia is leakage at the pump gland. The gas is extremely searching, and even at the comparatively low pressure of 30 lb. per square inch above the atmosphere it will readily find its way through an ordinary gland; while at the pressure existing in the condenser, which may be taken at from 150 to 180 lb. per square inch, this tendency is of course much aggravated. In order to minimize the leakage and to simplify the construction of the gland, the pumps are frequently made single acting, as in this way the gland is exposed only to the refrigerator pressure, which is seldom above 30 lb. It is also usual for glycerine, or some lubricant that does not saponify with ammonia, to be injected into the pump, so as to form a liquid seal for the gland, and in some cases for the piston as well; this is the general practice in the United States. In Germany, on the other hand, where the compression machine has been very largely applied, the double acting pump is more usual. To lessen leakage, Linde provides a chamber in the gland box, into which glycerine or some suitable lubricant is constantly forced at a slightly greater pressure than that prevailing in the condenser, so that the tendency is for the lubricant to leak inward, instead of ammonia outward. Any lubricant that does get into the pump passes out with the ammonia, and is separated from it in a suitable vessel. Up to the present time, so few ammonia compression machines have been constructed in England, that as yet no general practice has been established; but on the whole, the feeling seems to be in favor of the single acting pump.

With regard to the other parts of the apparatus, but little need be said. Wrought iron coils or zigzags are used for both the condenser and the refrigerator, their precise form depending on the fancy of the designer. The refrigerator is generally combined with the ice tanks, the cooling pipes being placed either below or at the side of the moulds, sometimes in a separate compartment and sometimes in the same tank. With the cell system an independent refrigerator is used, the cooled brine being circulated by a pump in a similar manner to that described for the ether system. Owing to the low temperature which may be attained by the

* *Journal of the Society of Arts*, 1883, vol. xxxi., page 77.

use of ammonia, care has been taken in the selection of a brine that will not congeal with the degree of cold to which it will be subjected. A solution of calcium or magnesium chloride in water is generally used. The mechanical work expended in compressing ammonia may be accounted for in a precisely similar manner to that expended in the compression of ether. Notwithstanding that the degree of compression is so much greater with ammonia than with ether, the energy expended in compressing, heating, and delivering the gas is less, owing to the much smaller weight of ammonia required to produce a given refrigerating effect, the weights being in the inverse ratio of the heats of vaporization, or as 1 to 5·45. For this reason the cost of making ice is much less with ammonia than with ether, one ton of coal being capable of producing as much as 12 tons of ice in well constructed ammonia apparatus having a capacity of 15 tons per 24 hours. With coal at 15s. a ton, the cost of making ice by the ammonia compression system may be taken at about 3s. 9d. per ton for a production of 15 tons per 24 hours, exclusive of allowances for repairs and depreciation. Through the courtesy of the manager of the Linde British Ice Company, the author is enabled to give the following results of a test made by a committee of Bavarian engineers with a machine erected in a brewery in Germany. The test he believes was carried out in an impartial manner; and though it is not put forward by the Linde Company as showing the results attained in the ordinary working of their machines, it will nevertheless be of interest as indicating what may be expected under the most favorable conditions.

Nominal capacity of machine, tons of ice per 24 hours	24 tons.
Actual production of ice, tons per 24 hours	39·2 tons.
Actual production of ice, lb. per hour	3,659 lb.
Heat units abstracted per hour in ice making	731,800 units.
Indicated horse power in steam cylinder, excluding that required for circulating the cooling water and for working cranes	53 I. h. p.
Indicated horse power in ammonia pump	38 I. h. p.
Thermal equivalent of work in ammonia pump, units per hour	97,460 units.
Ratio of work in pump to work in ice making	1 to 7·5.
Total feed water used in boiler, lb. per 24 hours	26,754 lb.
Ratio of coal consumed to ice made, taking an evaporation of 8 lb. of water per lb. of coal	1 to 26·3.

In this case the pumps were driven by a Sulzer engine, which developed one indicated horse power with 21·8 lb. of steam per hour, including the amount condensed in steam pipes. Ammonia compression machines are manufactured in this country by Messrs. Siebe, Gorman & Co., the Birmingham Refrigeration Company, and the Linde British Ice Company.

System C.—This is known as the absorption process, and was first applied by Carre about 1850. The principle employed is chemical or physical rather than mechanical, and depends on the fact that many vapors of low boiling point are readily absorbed by water, but can be separated again by the application of heat to the mixed liquid. A considerable number of machines in which ammonia was used in combination with water as an absorbent were made by Carre in France; but no very high degree of perfection was arrived at, owing to the impossibility of getting an anhydrous product of distillation; the ammonia distilled over contained about 25 per cent. of water, which caused a useless expenditure of heat during evaporation, and rendered the working of the apparatus intermittent. Taking advantage of the fact that two vapors of different boiling points, when mixed, can be separated by means of fractional condensation, Rees Reece brought out in 1867 an absorption machine in which the distillate was very nearly anhydrous. The action of the machine was briefly as follows: Ordinary liquid ammonia of commerce, of 0·880 specific gravity, was heated, and a mixed vapor of ammonia and water was driven off. By means of vessels termed the analyzer and the rectifier, the bulk of the water was condensed at a comparatively high temperature, and run back to the generator; while the ammonia passed into a condenser, and there assumed the liquid form under the pressure produced by the heat, and the cooling action of water circulating outside. The nearly anhydrous liquid was then utilized in a refrigerator in the ordinary way; but instead of the vapor being drawn off by a pump, it was absorbed by cold water or weak liquor in a vessel called an absorber, which was in communication with the refrigerator; and the strong liquor thus formed was pumped back to the generator, and used over again. This apparatus was afterward improved by Stanley, who introduced steam coils for causing the evaporation in the generator; and then by Pontifex & Wood, who have succeeded in bringing the absorption machine to a considerable state of efficiency. Their apparatus, as applied to the cooling of liquids, consists of a generator, containing the coils, to which steam is supplied from an ordinary boiler; an analyzer, a rectifier and condenser; a refrigerator or cooler, in which the nearly anhydrous ammonia obtained in the condenser is allowed to evaporate; an absorber, through which weak liquor from the generator continually flows and absorbs the anhydrous vapor produced in the refrigerator; an economizer or interchanger, by means of which the cold strong liquor from the absorber is heated by the hot weak liquor passing from the generator to the absorber; and pumps for forcing the strong liquor produced in the absorber back into the analyzer, where, meeting with steam from the generator, the ammonia is again driven off; the process being thus carried on continuously.

Assuming the action of the economizer to be perfect—which, of course, is a condition never met with in practice—all the heat given out by the steam in the generator coils would be found in the water issuing from the condenser, less that portion directly lost by radiation and conduction. In this case the total heat expended would be that required to vaporize the ammonia, and the water, which in the form of steam unavoidably passes off with the ammonia to the rectifier and condenser, plus the heat lost by radiation and conduction. In the refrigerator, the liquid ammonia in becoming vaporized will take up the precise quantity of heat that was given off during its cooling and liquefaction in the condenser, less the amount due to difference in pressure, and less also the small amount due to the difference in temperature between the vapor entering the condenser and that leaving the refrigerator. Again, when the vapor enters into solution with the weak liquor in the absorber, the heat taken up in the refrigerator is given to the cooling water, subject to slight corrections for differences of pressure and temperature. Supposing there were no losses, therefore, the heat given up by the steam in the generator, plus that taken up by the ammonia in the refrigerator, would be precisely equal to the amount taken off by the cooling water from the condenser, plus that taken off from the absorber. The sources of loss are:

Inefficiency of the economizer.

Radiation and conduction from all vessels and pipes that are above normal temperature.

Useless evaporation of water which passes into the rectifier and condenser.

Conduction of heat into all vessels and pipes that are below normal temperature.

Water passing into the refrigerator along with the liquid ammonia.

It will have been seen that the heat demanded from the steam is very much greater in the absorption system than in the compression. This is chiefly due to the fact that in the absorption system the heat of vaporization acquired in the refrigerator is rejected in the absorber, so that the whole heat of vaporization required to produce the ammonia vapor prior to condensation has to be supplied by the steam. In the compression system the vapor passes direct from the refrigerator to the pump, and power has to be expended merely in raising the pressure and temperature to a sufficient degree for enabling liquefaction to occur at ordinary temperatures. On the other hand, a great advantage is gained in the absorption machine by using the direct heat of the steam, without first converting it into mechanical work; for in this way its latent heat of vaporization can be utilized by condensing the steam in the coils and letting it escape in the form of water. Each pound of steam passed through can thus be made to give up some 950 units of heat; while in a steam engine using 2 lb. of coal per indicated horse-power per hour, only about 160 units are utilized per lb. of steam, without allowance for mechanical inefficiency. In the absorption machine also the cooling water has to take up about twice as much heat as in the compression system, owing to the ammonia being twice liquefied, namely, once in the condenser and once in the absorber. It is usual to pass the cooling water first through the condenser and then through the absorber. The cost of producing clear block ice in this country, with an absorption machine of 15 tons capacity per twenty-four hours, may be taken at about 4s. per ton, with good coals at 15s. per ton, exclusive of allowance for repairs and depreciation. About 10 tons of ice can be made per ton of coal consumed, assuming an evaporative duty of 8 lb. of water per lb. of coal.

System D.—In this, which is known as the binary absorption system, liquefaction of the refrigerating agent is brought about partly by mechanical compression and partly by absorption; or else the refrigerating agent itself is a compound of two liquids, one of which liquefies at a comparatively low pressure, and then takes the other into solution by absorption. An apparatus of the first kind was brought out in 1869 in Sydney by Messrs. Mort & Nicolle, who used ammonia, with water as an absorbent. The machine consisted of an evaporator or refrigerator, a pump, and an absorber. The evaporator was supplied with strong ammonia liquor, which was vaporized by means of the reduction of pressure induced by the pump, and so abstracted heat from the liquid to be cooled. The weak liquor passing out at the bottom of the evaporator was led by pipes to the pump, where it met with the ammonia vapor, along with which it was forced through cooling vessels under sufficient pressure to cause the solution of the ammonia; and the strong liquor thus formed was again passed into the evaporator. This machine was only used by the inventors in Australia, so far as the author is aware; and he has no particulars as to fuel consumption or cost of working. It was not likely, however, to be a very economical apparatus, because the whole of the water entering the evaporator with the ammonia had to be reduced in temperature, giving up its heat to the ammonia vapor, and to that extent preventing the performance of useful cooling work. But this disadvantage was in some degree compensated for by reducing the temperature of the strong liquor before it entered the evaporator, by means of an interchanger, through which the very cold weak liquor passed on its way to the pump.

In machines of the second kind, in which both liquids are evaporated at a low temperature, the foregoing objection does not exist; and though this mode of working has not as yet been introduced into this country, it has been successfully employed in the United States for several years by Messrs. De Motay & Rossi. The liquid used is a mixture of ordinary ether and sulphur dioxide, and has been termed ethylo sulphurous dioxide; its adoption was decided on after a series of experiments with numerous other combinations of ethers and alcohols with acids. In these investigations it was found that liquid ether at ordinary temperatures possessed an absorbing power for sulphur dioxide amounting to some 300 times its own volume; while at 60° Fah. the tension of the vapor given off from the binary liquid was below that of the atmosphere. In working, both liquids evaporate in the refrigerator, under the influence of the pump; and in the condenser the pressure never exceeds that necessary to liquefy the ether. The compressing pump has less capacity than would be required for ether alone, but more than for pure sulphur dioxide. As to the cost of making ice by this process, the author has no particulars; but he believes it to be somewhat less than with ether. An interesting application of the binary system has lately been made by Raoul Pictet, who found that by combining carbon dioxide and sulphur dioxide he could obtain a liquid whose vapor tensions were not only very much less than those of carbon dioxide, but were actually below those of pure sulphur dioxide at temperatures above 78° Fahr. This is a most remarkable and unlooked for result, and may open up the way for a much greater economy in ice production than has yet been obtained. As to the results that have been obtained with this process, the author has no definite particulars; but he understands it is stated to give a production of 35 tons of ice per ton of coal.

3.—*Machinery by which a Gas is Compressed, partially Cooled while under Compression, and further Cooled by Subsequent Expansion.*

This subject having been dealt with in a paper on "Machines for Producing Cold Air," which the author had the honor to read before the members of this Institution in January, 1881, the remarks under this head will therefore to a large extent be supplementary to that paper, and will refer chiefly to improvements which have been effected since that date. It will be convenient, however, and will tend to a better appreciation of the subject, to present concisely some brief considerations respecting the physical laws relating to this system of refrigeration, even at the risk of repeating part of the matter touched upon in the previous paper. The intrinsic energy of a permanent gas, or its capacity for performing work, depends entirely upon its temperature. Increase of pressure imparts no additional energy, but merely places the gas in such a condition relatively to some other pressure as to enable advantage to be taken of its intrinsic energy by expansion. Thus, a pound of air at ordinary atmospheric pressure has the same intrinsic energy as a pound of air at 50 lb. pressure above the atmosphere so long as their temperatures are the same; but in the former case no part of the energy can be made use of by expansion without the removal of, at least, a part of the equal and opposite resistance of the atmosphere, while in the latter case expansion can take place freely until the pressure is reduced to that of the atmosphere. As mechanical work and heat are mutually convertible, it is obvious that, if during expansion a gas is caused to perform work on a piston, its supply of heat must be drawn on to an extent measured by the thermal equivalent of the work done, provided no extraneous source of heat exists from which the deficiency can be made good; and the gas after expansion will be colder than it was before expansion. Expansion behind a piston without the addition of heat from an extraneous source is called adiabatic expansion; and the following are the relations between temperature, volume, and pressure for any two points in the same adiabatic curve:

$$\frac{t}{t_1} = \left(\frac{v_1}{v}\right)^{\gamma - 1} = \left(\frac{p}{p_1}\right)^{\frac{\gamma - 1}{\gamma}}$$

where t and v and p denote absolute temperature, volume, and absolute pressure before expansion, and t_1 v_1 p_1 those after expansion, while γ is the ratio of the specific heat under constant pressure to that with constant volume. During adiabatic compression the converse results take place, and the same relations exist between absolute temperature, volume, and absolute pressure as during expansion; t_1 v_1 p_1 denoting those before compression, and t v p those after compression.

In the succeeding remarks, reference will be made to the use of ordinary atmospheric air alone; for although in one or two special instances this class of machinery has been applied to the cooling of some of the more volatile hydrocarbons, its almost universal application at the present time is for the cooling of air, which therefore will alone be dealt with. The amount of aqueous vapor present in the atmosphere varies from that required to produce saturation down to about one-fifth of that quantity. At any given temperature a volume of saturated air can contain only one definite amount of vapor in solution; and if from any cause additional moisture be present, it cannot exist as vapor, but appears as water in the form of fog or mist. The temperature of saturation, or the dew point, varies according to the quantity of vapor in solution; the smaller the quantity, the lower is the dew point. The capacity of air for holding moisture is also affected by pressure; a diminution in volume under constant temperature reduces this capacity in direct proportion.*

In the former paper, reference was made to various means that had been devised for ridding the air more or less completely of its contained moisture, in order to obviate as much as possible the practical evils resulting from its condensation and freezing; this being at that time considered one of the most important points in the construction of cold-air machinery.

Since then, however, experience has demonstrated that these evils were much exaggerated, and that the condensation of the vapor and deposition of the moisture in the ordinary cooling process after compression, which is common to every cold air machine, are amply sufficient to prevent any serious deposition of ice about the valves and in the air passages; provided, first, that these valves and passages are well proportioned, and secondly, that proper means are adopted for obtaining in the coolers a deposition of the condensed vapor, which would otherwise pass with the air into the expansion cylinder in the form of fog, and become converted into ice.

Reference to the table shows that, if the compressed air be thoroughly deprived of its mechanically suspended moisture, the amount of vapor entering the expansion cylinder is extremely small. Another matter from which the mystery has now been dispelled is the meaning of the term "dry" air, so much used by the makers of cold-air machinery; this is a point that was just touched upon toward the close of the discussion upon the previous paper. No doubt it is still to a large extent popularly supposed that, unless the air be subjected in the machine to some special drying process, it will be delivered from the expansion cylinder in a moist or damp state, and in consequence be unfitted for use in the preservation of perishable food and for other purposes. But no such state could really exist; for whether the air be specially "dried" or not, its humidity when delivered from the expansion cylinder is precisely the same, so long as its temperature and pressure remain the same, inasmuch as in practice it is always in a saturated condition for that pressure and temperature.

The difference lies in the amount of ice formed, which of course is greater if the amount of moisture entering the expansion cylinder is greater; but this quantity, as has already been stated, may in the author's opinion be brought down within perfectly convenient limits by a proper construction of the cooling

* For the quantity of vapor necessary to produce saturation, reference may be made to the table and formula given in the appendix to the paper on "Machines for Producing Cold Air." (*Proceedings*, 1881, page 122.)

vessels. In his latest machines, therefore, all special drying apparatus has been dispensed with; the air being simply compressed, passed through a surface cooler, and expanded back to atmospheric pressure. On the other hand, Messrs. Haslam & Co., of Derby, still apply an interchanger, on somewhat the same principle as that previously described in connection with the Bell-Coleman machine (*Proceedings*, 1881, page 111); and it would be interesting if some definite particulars could be furnished to show what practical effect this interchanger really has.

Messrs. Hall's cold-air machine is of both horizontal and vertical type, the latter applying to the smaller sizes. In either case, when combined with a steam engine, it consists of three double acting cylinders placed side by side, at the end of a frame or bedplate; the cylinders are furnished with the usual moving parts, and the connecting rods work on three crank pins on a common crank shaft. One of the cylinders is used with steam in the ordinary manner, for giving the requisite motive power. Of the two others, one is for compressing and one for expanding the air. The coolers are of the multitubular type for surface cooling, and are placed in the bedplate or frame. The valves for the compression and expansion cylinders are slides of somewhat peculiar design, worked from a pair of weigh-bars, one for the main and the other for the expansion slides. The valves are placed on the under side of the cylinders, which renders them rather difficult of access; but in the larger sizes of machines the cylinders are raised, and worked down to the shaft at an angle, which gives a little more room below. The compressor is water-jacketed; and so far as the author is aware, no special arrangement for drying the air is employed. The Haslam dry-air refrigerator, which has been very largely adopted, is also made both horizontal and vertical, the horizontal type applying to large machines, and the vertical to those of small size. The cylinders are double-acting, and their arrangement with regard to one another varies in different classes of machines. The compressor is water-jacketed, and discharges into surface coolers placed in the bed. The compressed air, after having been cooled in the ordinary way by water, is further reduced in temperature in an interchanger, by the action either of the spent cold air on its way from the chamber in which it has been utilized, or of the cold air as it leaves the expansion cylinder; and in this manner a further condensation and deposition of moisture are brought about. The expansion cylinder presents no peculiarity in design, with the exception of the exhaust valves, which are separate from those admitting the air, and are so arranged as to offer as little obstruction as possible to the passage of the air. The Haslam Company also manufacture the Bell-Coleman machine, which was described in the author's previous paper.

In a horizontal dry air refrigerator of the author's design, of the type used for delivering from 20,000 to 60,000 cubic feet of cold air per hour, the compressor is double acting, and the expansion cylinder single acting. They are placed close together, tandem fashion, leaving room for examination of the piston, with one rod common to both cylinders. In this way the coldest part of the expansion cylinder is removed from the hottest part of the compressor.

The air valves are circular slides of phosphor bronze, actuated by eccentrics in the usual way. This kind of valve enables the ports to be made very short and direct; and besides being noiseless in action, it allows of a high piston speed being attained. No trouble has been experienced with regard to wear, not a single case having occurred in which the valves have had to be replaced, notwithstanding that some have been in almost constant work since 1882.

The air enters the compressor by pipes, and after being compressed passes by another pipe to the coolers, which are placed in the bedplate, and consist of a couple of iron vessels containing clusters of solid-drawn Muntz-metal tubes of ¾ inch external diameter. Water is circulated through the inside of the tubes by a pump, the supply passing in by one pipe, through the tubes, and away by another pipe to the compressor jacket, whence it escapes by a third pipe. The water condensed and deposited from the air in the coolers is blown off from time to time by means of drain cocks, or may be discharged automatically.

The compressed air passes through one cooler and returns through the second, being cooled to within some 5° or 6° of the initial temperature of the cooling water, which circulates in a direction opposed to that of the air. The quantity of water required is at the rate of from 30 to 40 gallons for every 1,000 cubic feet of cold air discharged at atmospheric pressure, that is, from three to four times the weight of the air; but the quantity varies in different machines, according to the efficiency of the apparatus. From the coolers, the air passes by a pipe to the expansion cylinder; and after performing work upon the piston, and returning about 60 per cent. of the power expended in its compression, it is exhausted from a passage, having become cooled down to from 70° to 90° below zero Fah.

The steam cylinder is overhung from strong brackets cast on the bedplate, and is arranged so that a jet or surface condenser can be placed below, with an air pump worked from a continuation of the piston rod; the space occupied is thus practically the same, whether the engine is non-condensing or condensing. The arrangement also lends itself readily to the application of a second steam cylinder, tandem fashion, for working on the compound principle.

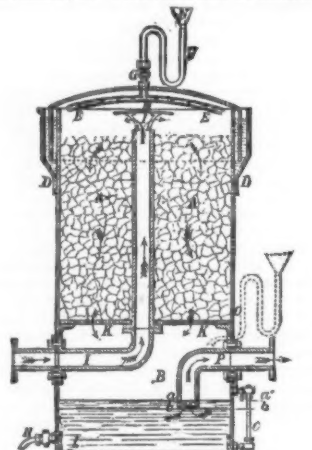
For land machines to deliver more than 60,000 cubic feet of cold air per hour, the vertical type is adopted, and the compressor is made single acting as well as the expansion cylinder, while a horizontal compound condensing steam engine is used for giving the necessary motive power. A machine to deliver 285,000 cubic feet of cold air per hour, for cooling a large market, is now being designed in this way. The compressor is furnished with an internal pipe, from which a spray of cold water continually plays on the back of the piston and on the sides of the cylinder, but never comes in contact with the air itself. In order to secure compactness and simplicity, machines delivering less than 20,000 cubic feet of cold air per hour are made, the compressors being single acting. The smaller sizes are very frequently made on the vertical plan, for use both on land and on board ship. The design is practically the same as that of the horizontal machines; but in the vertical type the coolers are cast in one piece with the frame, instead of being separate. There is a vertical machine of similar design, but arranged for being driven by a belt. The main objects kept in view by the author in designing all the foregoing machines are economy of production, efficiency, and simplicity. Some thirty of these refrigerators, of one form or the other, have now been made and put to work since 1884; and in not one single instance has any breakdown occurred in working, nor have any repairs been required beyond those that would have been necessary to an ordinary steam engine of good construction. In many cases machines made in England have been packed and shipped to Australia, and to North and South America and other foreign countries, where they have been erected and put to work without the assistance of any skilled labor from this country. With regard to the power expended in cooling air on this plan, it may be stated that, in the best machines of large size now made, a weight of 1,000 lb. of air per hour can be reduced from 60° above to 80° below zero, with cooling water at 60° Fah., with the expenditure of about 18 indicated horse-power. This is equal to an abstraction of 916 units per pound of coal, with an engine using 2 lb. of coal per indicated horse-power per hour.

(To be continued.)

THE PREVENTION OF NAPHTHALENE DEPOSITS.

THE apparatus shown in the accompanying illustration has been designed by Herr Fleischer, of Frankfort on the Main, for the purpose of preventing the deposition of the naphthalene formed in the manufacture of illuminating gas. The appliance was described and illustrated in a recent number of the *Journal fur Gasbeleuchtung*, to which we are indebted for the following particulars as to its operations.

The receiver (which may be either round or square) is filled in its upper part, A, with some porous material—such as pounded clinker, small pieces of coke, etc.—separated from the lower part, B, by a perforated screen, K. The cover, which dips down into the hydraulic seal caps, D, is provided at the top with a U-shaped tube, F, ending in a funnel, N. This tube can be closed at its lower extremity by a cock, G; and in the interior it is in direct connection with the spiral perforated pipe, E. Some such substance as petroleum naphtha, ether containing a carburet of hydrogen, coal naphtha, etc., is poured into the funnel, N, until the porous material in the space, A, of the receiver is completely saturated. The portion that filters through is collected in the lower part, B; and its height is indicated outside by the gauge, C. A movable plate, M, resting upon the pipe, I, prevents liquids and other substances from entering. The cock, H, serves the purpose of drawing off the naphtha, and the screw, L, for the removal of any tar which may be precipitated. When required, a U-pipe may be screwed on for the purpose of pouring in the naphtha, as shown by the dotted lines at O.



The action of the apparatus is as follows: The gas enters through the pipe, I, in the direction indicated by the arrows, passes through the saturated porous substance in the space, A, and then through the screen, K, into the lower division, B. In the passage of the gas through A, the naphthalene is separated, or rather destroyed, to a great extent; and the gas, thus purified, passes out through the pipe, P. If, however, owing to the increased production of gas, the use of different kinds of coal, or any other circumstance, this method of purification is found to be insufficient—a fact which will make itself apparent by additional pressure in the mains—the quantity of naphtha in the lower part of the receiver may be easily augmented; the level of the liquid being raised to the point, *a*, as indicated by the gauge at *a*'. By thus causing the gas to pass through the bent pipe, P, which is immersed in the liquid to the extent of a few centimeters only, a thorough washing and impregnation of the gas with naphtha is effected.

From this it will be seen that the efficiency of the apparatus may be increased or reduced according to requirements; in the latter case, by employing it as a kind of scrubber only, allowing the level of the liquid to sink to or below the point, *b*. Or, without in any way impairing the efficacy of the apparatus, the gas can be made to pass through it in the reverse direction—entering it through the pipe, P, and leaving it by the pipe, I. In this case the washing of the gas with naphtha is the first process, to be followed by the drying stage in the passage through the porous material. If the last-named proceeding is resorted to, the naphtha must not be poured in from the top, but introduced from below; the siphon, O, being inserted. With this arrangement, the porous material will, of course, remain dry.

A certain quantity of naphtha must always be left in the reservoir, B, when the apparatus is used for the purpose of purifying the gas from naphthalene; this being constantly absorbed by the porous material in the space, A; or rather it evaporates. When there is no need to purify the gas from naphthalene—for instance, during the summer months—the gas may be conducted past the apparatus without going through it; thus affording an opportunity for removing the porous material. The apparatus may, however, be filled at any time, and brought into use at once.

In determining the position to be occupied by the apparatus, care should be taken to ascertain exactly where the deposit of naphthalene commences. If it occurs in the early stage of the passage of the gas from the condenser to the purifiers, it would seem to be advisable to place the appliance in front of the latter. In any case, it is desirable to fix it after the purifiers—that is to say, between these and the station meter—inasmuch as, by adopting this course, the apparatus does not become impregnated with tarry matter from the gas. Besides, the naphtha absorbed by the gas remains it, and increases the illuminating power; whereas this would not be the case if, after having been impregnated with naphtha, the gas were a second time subjected to purification.—*Jour. Gas Lighting.*

THE PURIFICATION OF WATER BY ALUM.

By Prof. PETER T. AUSTEN, Ph.D., F.C.S., Rutgers College (State Scientific School), New Brunswick, N. J.

THERE is no subject which gives the manufacturer greater anxiety, at times, than the water which he is using in the works. Even where he is so lucky as to be located on the banks of some clear and sparkling brook, and hence is free from many of the troubles known to his less fortunate brethren, his brook may not seldom get into a troubled state, and refuse to be clarified of its suspended clay and other matters by any ordinary process available to him. In no industry is this vexation from dirty water greater than in dyeing. Hence it is a matter of great importance, meaning a saving of hundreds and sometimes thousands of dollars, to have a simple means of clearing water, so that it can be used in ordinary manufacturing processes, and yet not in any way injure the properties of the water for subsequent use.

For large works which use water requiring continual purification, some constant process should be employed, as the Hyatt filter for instance. The Norfolk and New Brunswick hosieries filter all the water which they use in their works, and in this way get a most beautifully clear and sparkling water out of a rather muddy-looking source (the canal). In this establishment four large Hyatt filters are used, and I have had occasion to satisfy myself of the efficacy of their working. But there are many small establishments which could not afford to put in large filters and pumps, and there are many others which do not require to purify their water, except at certain seasons of the year. Hence some simple process is needed, one that can be worked without trouble and which will give a clear water, and by which no detrimental qualities shall be added to the water.

In a recent report to the State Geologist of New Jersey on the purification of drinking water by alum, I have, in conjunction with Prof. F. A. Wilber, made this matter of the clarification of water the subject of a special investigation. The use of alum as a purifier of water seems to date back a long time. Particular attention was directed to its use by Jeunet in 1865, in an article published in the *Moniteur Scientifique*. He found that 0·4 grm. of alum to a liter of water (23·3 grains to a gallon) rendered it drinkable, even when it was quite full of foreign matter. The time taken for this clarification was from seven to seventeen minutes.

Alum is a double sulphate of potassium and aluminum, and in this case breaks into potassium sulphate, which remains in solution, and a basic aluminic sulphate. This basic aluminic sulphate, the composition of which is undetermined, precipitates as a more or less gelatinous and flocculent mass, and carries down with it the foreign matters and humus bodies. The sulphuric acid set free in the formation of the basic aluminic sulphate attacks the earthy and alkaline carbonates which are always present, and forms with them sulphates, setting the carbonic acid free. Aluminic sulphate acts like alum. Ferric chloride (perchloride of iron) acts in the same way as alum.

In late years an extensive use has been made of alum in the many processes of purifying water, sewage, etc. It is not improbable that, aside from its effect in precipitating matter mechanically by envelopment within the precipitating basic aluminic sulphate, the alum exerts a distinct coagulative action on the albuminous substances in the water, rendering them insoluble, and thus causing their precipitation; perhaps the same or similar effect that alum produces in the tawing of leather.

Alum has the great advantage that it is cheap, can be obtained everywhere, and is not highly poisonous. Thirty grains can be given at a dose, and the dose repeated four times a day without danger. Then again it has another very great argument in its favor, and that is its cheapness. To get practical results from the purification by alum, it is evident that it must be added in very small amounts. The amount of alum used by Jeunet seemed to be unnecessarily high. On repeating his experiments, using New Brunswick hydrant water, which at the time the experiments were made carried considerable clayey matter, we found 23·3 grains of alum to a gallon produced an immediate coagulation of the suspended matters in the water, but no settling took place under six hours or more, as stated by Jeunet. On longer standing, however, the water settled perfectly, and was as clear as could be wished for.

The water after treatment had no taste of alum, but gave a perceptible test for alumina, showing that some alum remained in solution. Our next procedure was to determine what was the minimum amount of alum that was needed to clarify this particular water. Tall cylinders were filled with water, and alum added in varying amounts. Depending on the amounts of alum added, gelatinous precipitates settled out after a greater or lesser lapse of time.

It would be impossible to make any general rule for the addition of alum to water, because the amount of impurities will of course be very much greater in one sample of water than in another, but we were able to determine what the practical minimum limits were for this particular water. 1·2 grains of alum to the gallon was about as small an amount of alum as it seemed practical to use to get a perfect separation of the impurities. The larger the amount of alum added to the water, the more quickly will the separation take place;

the smaller the amount added, the longer will the water have to stand before a clarification will be effected.

Again, large bodies of water will be precipitated by smaller amounts of alum than one would infer from experiments on a small scale, as the mechanical action of the precipitate here, in enveloping and carrying down suspended matter, is greater in a large body of water than in a small one. It will be better, however, to err on the side of too large an amount, for even then the amount of alum added will be insufficient to impart any detrimental properties to the water.

Sixteen gallons of the city water were treated with 31 grains of alum, and the whole allowed to stand. After 48 hours the precipitation seemed complete, and the bottom of the vessel was covered with a brownish slimy deposit. This substance after being dried gave 59·28 per cent. of ash, which contained silica and alumina in relatively large amounts. The clear water gave no reaction for alumina, showing that there was no free alum in solution. The addition of more alum to the water failed to produce any further precipitation, showing that all the matter precipitable by alum had been thrown down.

It may hence be inferred that the addition of two grains of alum to a gallon of water will clarify it by standing. Some waters may require less, and some may require a longer standing than 48 hours, but this is a matter very easily determined for any particular case which may arise.

The water, after precipitation has taken place, is perfectly clear and sparkling, and has neither taste nor smell imparted to it. For use in the dyehouse, there can be no possible objection made to it. The most practical way of applying this method in clarifying water for use in manufacturing, where filters are not used, will be as follows: Two vats, or hogsheads, or similar deep tanks, are filled with the water, and treated with alum at the rate of half an ounce of alum for every hundred gallons of water.

The alum should be dissolved in a little hot water, so that it can be mixed with the large bulk of water without difficulty. The mixing can be done with a long handled dyer's stirrer. A few minutes' stirring will suffice to mix the alum and the water very thoroughly. After the mixing has been done, the water should be allowed to stand undisturbed for 48 hours or until the water clarifies, which can be easily seen by its appearance. If the clarification takes place in a less time, so much the better. The water is now racked off for use. When the vat has been emptied to as low a level as is possible without disturbing the sediment, the plug in the bottom should be knocked out and the vat cleaned out with a strong jet of water. The slimy deposit is easily dislodged, and washed away by a stream of water.

While one reservoir is thus being used, the other is full of water precipitating, so that the supply is continuous. The best means of drawing the water from the tanks without disturbing the sediment is about as follows: The pipe should enter the side of the vat and pass to the middle, and there be bent upward so as to end about a foot above the bottom of the vat. The water is thus drawn downward, and no agitation of the bottom is produced. If the pipe is turned toward the bottom of the vat, the current of water will disturb the sediment.

I think that this method will be found of very great value to many works which now have trouble with their water in the rainy season, and I can call to mind off hand several which could use it to advantage. A few trials with the beautifully clear water produced by the alum treatment will make the hands feel loth to go back to the natural water, even at its best. I am quite certain that many streams not now available to the manufacturer can be made so by this treatment.—*Textile Colorist.*

FLAME CONTACT.—A NEW DEPARTURE IN WATER HEATING.*

By THOMAS FLETCHER.

IT is my intention to prove to you, on theoretical grounds, and also by experimental demonstration, in such a manner as will admit of no possible doubt, that the present accepted system of water heating, by gaseous or other fuel, is a very imperfect means for an end, and is, both in theory and practice, essentially faulty. My statements may appear bold, but I come prepared to prove them in a manner which I think none of you will question, as the matter admits of the simplest demonstration. I will, in the first place, boil a specified quantity of water in a flat-bottomed vessel of copper. The time required to boil this you will be able to take for yourselves, as the result will be visible by the discharge of a strong jet of steam from the boiler. I will then take another copper boiler of the same form, but with only one-half the surface to give up its heat to the water, and will in this vessel boil the same quantity of water with the same burner in a little over one-half the time, thus about doubling the efficiency of the burner, and increasing the effective duty of the heating surface nearly fourfold, by getting almost double the work from one-half the surface. The subject is a comparatively new one, and my experiments are far from complete on all points, but they are sufficiently so to prove my case fully. As no doubt you are all aware, it is not possible to obtain flame contact with any cold, or comparatively cold, surface. This is readily proved by placing a vessel of water with a perfectly flat bottom over an atmospheric gas burner; if the eye is placed on a level with the bottom of the vessel, a clear space will be seen between it and the flame. I cannot show this space on a lecture table to an audience, but I can prove its existence by pasting a paper label on the bottom of one of the boilers, and exposing this to the direct impact of a powerful burner during the time the water is being boiled, and you will see that it comes out perfectly clean and uncolored. Now, it is well known that paper becomes charred at a temperature of about 400° Fah., and the fact that my test paper is not charred proves that it has not been exposed to this temperature, the flame being in fact extinguished by the cooling power of the water in the vessel. I need hardly remind you that the speed with which convected or conducted heat is absorbed by any body is in direct ratio to the difference between its own temperature and that of the source of heat in absolute contact with it; and therefore, as the source of the heat taken up by the vessel is nothing but unburnt gases, at a temperature below 400° Fah., the rate of absorption cannot, under any circumstances, be great, and the usual practice is to compensate for this inefficiency by an enormous extension of surface in contact with the water, which extension I will prove to you is quite unnecessary. You will see I have here a copper vessel with a number of solid copper rods depending from the lower surface; each rod passes through into the water space, and is flattened into a broad head, which gives up its heat rapidly to the water. My theory can be stated in a few words: The lower ends of the rods, not being in close communication with the water, can and do attain a temperature sufficiently high to admit of direct flame contact; and as their efficiency, like that of the water surface, depends on the difference between their own temperature and that of the source of heat in absolute contact with them, we must, if my theory is correct, obtain a far greater duty from them. I do not wish you to take anything for granted; and although the surface of the rods, being vertical, can only be calculated for evaporating power at one-half that of a horizontal surface, as is usual in boiler practice, my margin of increased duty is so great that I can afford to ignore this, and to take the whole at what its value would be as horizontal surface, and still obtain a duty 50 per cent. greater from a surface which is the same in area as the flat-bottomed vessel on the fireside, but having only one-third the surface area in contact with the water. I do not, of course, profess to obtain more heat from the fuel than it contains, but simply to utilize that heat to the fullest possible extent by the use of heating surfaces beyond comparison smaller than what have been considered necessary; and to prove not only that the heating surface can be concentrated in a very small area, but also that its efficiency can be greatly increased by preventing close water contact, and so permitting combustion in complete contact with a part of the heating surface. I will now boil 40 oz. of water in this flat-bottomed copper vessel, and, as you will see, sharp boiling begins in three minutes fifteen seconds from the time the gas is lighted. The small quantity of steam evolved before this time is of no importance, being caused partly by the air driven off from the water and partly from local boiling at the edges of the vessel, owing to imperfect circulation. On the bottom of this vessel is pasted a paper label, which you will see is untouched by the flame, owing to the fact that no flame can exist in contact with a cold surface. It may be thought that, owing to the rapid conducting power of copper, the paper cannot get hot enough to char. This is quite a mistake, as I will show you by a very curious experiment.

I will hold a small plate of copper in the flame for a few seconds, and will then hold it against the paper. You will see that, although the copper must of necessity be at a temperature not exceeding that of the flame, it readily chars the paper. We can, by a modification of this experiment, measure the depth of the flameless space, as the copper, if placed against the paper before it has time to be previously heated, will, if not thicker than 1-40 inch, never become hot enough to discolor the paper, showing that the flame and source of heat must be below the level of a plate of metal this thickness. In repeating this experiment, I must caution you to use flour paste, not gum, which is liable to swell and force the paper past the limit of the flameless space, and also to allow the paste to dry before applying the flame, as the steam formed by the wet paste is liable also to lift the paper away and force it into the flame. I will now take this vessel, which has only one-half the surface in contact with the water, the lower part being covered with copper rods, 3-16 in. diameter, ⅝ in. centers apart, and 1½ in. long, and you will see that with the same burner as before, under precisely the same conditions, sharp boiling takes place in 1 minute 50 seconds, being only 13 seconds more than half the time required to produce the same result with the same quantity of water as in the previous experiment. Although the water surface in contact with the source of heat is only one-half that of the first vessel, and the burner is the same, we can see the difference, not only in the time required to boil the 40 oz. of water, but also in the much greater force and volume of steam evolved when boiling does occur. With reference to the form and proportions of the conducting rods, these can only be obtained by direct experiment in each case for each distinct purpose. The conducting power of a metallic rod is limited, and the higher the temperature of the source of heat, the shorter will the rods need to be, so as to insure the free ends being below a red heat, and so prevent oxidation and wasting. There are also other reasons which limit the proportions of the rods, such as liability to choke with dirt and difficulty of cleaning, and also risk of mechanical injury in such cases as ordinary kettles or pans; all these requirements need to be met by different forms and strengths of rods to insure permanent service, and, as you will see further on, by substituting in some cases a different form and type of heat conductor. To prove my theory as to the greater efficiency of the surface of the rods in contact with the flame as against that in direct contact with the water, I have another smaller vessel, which, including the rods, has the same total surface in contact with the flame, but only one-third the water surface as compared with the first experiment.

Using again the same quantity of water and the same burner, we get sharp boiling in two minutes ten seconds, being an increase of duty of 50 per cent., with the same surface exposed to the flame. The rods in the last experiment form two-thirds of the total heating surface; and if we take, as I think for some careful experiments we may safely do, one-half the length of the rods to be at a temperature which will admit of direct flame contact, we have here the extraordinary result that flame contact with one-third of the heating surface increases the total fuel duty on a limited area 50 per cent. This really means that the area in contact with the flame is something like six times as efficient as the other.

In laboratory experiments, it is necessary not only to get your result, but to prove your result is correct, and the proof of the theory admits of ready demonstration in your own laboratories, although it is unfit for a lecture experiment, at all events in the only form I have tested it. If you will take two ordinary metal ladles for melting lead, cover the lower part of one of these with the projecting rods or studs and leave the other plain, you will find, on melting a specified quantity of metal in each, that the difference in duty between the two is very small. The slight increase may be fully accounted for by the difference in the available heating surface reducing the amount of waste heat passing away, and this proves that flame contact, and therefore quick absorption of heat, takes place on plain surfaces as soon as these are above a certain temperature, which, in a metal ladle, very soon occurs. What the temperature is which admits of flame contact, I have, as yet, not been able to test thoroughly, and it will need some consideration how the determination of this is to be correctly made; at the same time, it is a question in physics which should be capable of being answered.

Let us now take the other side of the question. If the efficiency of a surface depends on flame contact, there must of course be flame, or at least gases of an extremely high temperature, and we therefore cannot expect this extraordinary increase of efficiency in any part of our boiler except where flame exists; and if these projections are placed in a boiler anywhere except in contact with flame, their efficiency must be reduced to that of ordinary heating surface. They are, of course, useful, but only in the same way as ordinary flue surface.

When we come to boilers for raising steam, which have to stand high pressures, we come to other difficulties of a very serious nature, which require special provision to overcome them. To put such rods as I have referred to in a boiler plate necessitates the plate being drilled all over with holes, causing a dangerous source of weakness, as the rods cannot be used as stays; further than this, they would render really efficient examination a matter of extreme difficulty, and would be liable to give rise to frequent and almost incurable leakages; but there is, fortunately, a very simple way to overcome this difficulty.

I have found that rods or points, such as I have described, are not necessary, and that the same results can be obtained by webs or angle ribs rolled in the plates. My experiments in this direction are not complete, and at present they tend to the conclusion that circular webs, which would be of the greatest efficiency in strengthening the flues, are not so efficient for heating as webs running lengthways with the flue, and in a line with the direction of the flame. This point is one which I am at present engaged in testing with experimental boilers of the Cornish and Lancashire type; and, as we have in gas a fuel which renders every assistance to the experimenter, it will not take long to prove the comparative results obtained by the two different forms of web.

Those of you who have steam boilers will, no doubt, know the great liability to cracking at the rivet holes in those parts where the plates are double; this cracking, so far as my own limited experience goes, being usually, if not always, on the fire side, where the end of the plate is not in direct contact with the water, where it is, in fact, under the conditions of one of the proposed webs. I think we may safely come to the conclusion that this cracking is caused by the great comparative expansion and contraction of the edge of the plate in contact with the fire; and it will probably be found that if the plates are covered with webs, the whole of the surface of the plates will be kept at a higher and more uniform temperature, and the tendency to cracks at the rivet holes will be reduced.

This is a question not entirely of theory, but needs to be tested in actual practice. There is another point of importance in boilers of the locomotive class, and those in which a very high temperature is kept in the fire-box, and this is the necessity of determining by direct experiment the speed with which heat can safely be conducted to the water without causing the evolution of steam to be so rapid as to prevent the water remaining in contact with the plates, and also whether the steam will or will not carry mechanically with it so much water as to make it objectionably wet, and cause priming and loss of work by water being carried into the cylinders. I have observed, in the open boilers I use, that when sufficient heat is applied to evaporate one cubic foot of water per hour from one square foot of boiler surface, the bulk of the water in the vessel is about doubled, and that the water holds permanently in suspension a bulk of steam equal to itself. I have, as yet, not had sufficient experience to say anything positively as to the formation or adhesion of scale on such surfaces as I refer to, but the whole of my experimental boilers have, up to the present, remained bright and clean on the water surface, being distinctly cleaner than the boiler used with ordinary flat surfaces. It is, I believe, generally acknowledged that quick heating and rapid circulation prevents, to some extent, the formation of hard scale, and this is in perfect accord with the results of my experiments. The experiments which I have shown you, I think, demonstrate beyond all question that the steaming power of boilers in limited spaces, such as our seagoing ships, can be greatly increased; and when we consider how valuable space is on board ship, the matter is one worthy of serious study and experiment. It may be well to mention that some applications of this theory are already patented. I will now show you, as a matter of interest in the application of coal gas as a fuel, how quickly a small quantity of water can be boiled by a kettle constructed on the principle I have described; and to make the experiment a practical one, I will use a heavy and strongly made copper kettle which weighs 6¾ lb., and will hold when full one gallon. In this kettle I will boil a pint of water, and, as you see, rapid boiling takes place in 50 seconds. The same result could be attained in a light and specially made kettle in 30 seconds, but the experiment would not be a fair practical one, as the vessel used would not be fit for hard daily service, and I have therefore limited myself to what can be done in actual daily work rather than laboratory results, which, however interesting they may be, would not be a fair example of the apparatus in actual use at present.

* A paper read before the Gas Institute meeting, London, June 9, 1886.

BLACK, glossy leather belts, made of japanned leather, can be improved in appearance by rubbing with linseed oil, but there is no suitable permanent blacking for them that also keeps their polish. There is no cure for their cracking as they grow old, or from rough usage.

AN IMPROVED METHOD OF CABLE WORKING.

By J. EBEL.

WHEN the length of time that has elapsed since the discovery that telegraphy was possible over long ocean cables is taken into consideration, one is forced to the conclusion that very little advance has been made in the systems of practically working such cables.

It is very probable, however, that many electricians have arrived at some method of improved working which, for some reason or other, they have not made known; and in reflecting on the small progress that has been made in this particular branch of electrical science, regard should be had to the fact that it is very

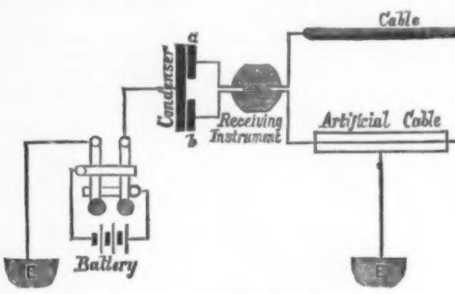


FIG. 1.

difficult for students and inventors to obtain access to the cables themselves, to test theories by experiments. It is very likely, in a great measure, due to the want of such facilities that some improved systems of working have not long ago been devised.

The accompanying diagrams illustrate the result of my own investigations.

For working the duplex system, where the bridge wire (sometimes called the fork) can be dispensed with, I maintain that the employment of a receiving instrument, with differentially wound coils, is preferable to the ordinary instrument.

In Fig. 1, a condenser is connected up, having three plates, or an equivalent thereto, two condensers with one plate of each joined. In this case, the middle plate is charged by the sending current, and the opposed, *a*, *b*, discharge themselves each through half of the coil of the receiving instruments, which are so

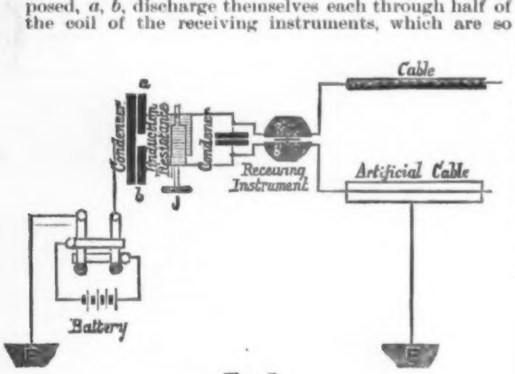


FIG. 2.

wound that when no current is received from the distant end of the circuit, their effects neutralize each other.

In the event of any inequality in the rate of absorption of the condenser plates, *a*, *b*, means are provided for inserting resistance in one or the other half of the instrument coils, or by rendering the influence of the coil on the needle or magnet by moving the coils to or from the needle.

For working greater length of cables, where the rate of speed depends on a well established balance, the plan indicated in diagram, Fig. 2, is employed.

In this arrangement, one additional subdivided condenser is inserted between the coils of the receiving instrument, a^1, b^1.

The capacity of the first condenser in regard to its plates, *a*, *b*, is as nearly as possible balanced. In the event of any difference in the absorption of the plates, a special form of adjustable induction resistance is em-

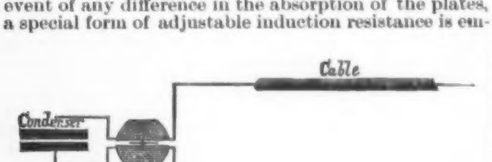


FIG. 3.

ployed, which is so constructed that, by means of a screw, I, turning to one or the other side, the difference in the unequal absorption of the upper and lower condenser plates can be adjusted to a nicety.

Diagram in Fig. 3 represents an improved system of working cables by simplex.

The receiving instrument is also supplied with a differentially wound coil or two separate coils.

The condenser is not, as hitherto, placed before or after the receiving instrument, but inserted between its coils, so that one plate is discharged through one part of the coil to earth and the other through the opposite part to cable; thus both discharges passing through the instrument will deflect the needle or coil in the same direction. By this means I purpose to utilize the induction between the coils in assisting the discharge, and so to neutralize the extra current developed in the said coil.

A higher rate of speed is obtained by this system.—*Electrical Review.*

DOMESTIC ELECTRICITY.

THE electric alarm shown in Fig. 1 is called by Mr. H. Levy, its manufacturer, a "chronophone." It consists of a mahogany box having the form, externally, of a watch stand. Inside of this there is an electric bell and two small Leclanche couples, the exciting liquid of which is mixed with sand, so that if upset no accident shall occur. The upper part of the stand is provided with a hook for supporting a watch, the crystal of which, having a small aperture in the center, supports a metallic rod. The object of this latter is to establish an electric contact every time the hour hand reaches it. It is capable of being brought over the desired figure on the dial by revolving the crystal, to which it is fixed by a rivet, and which insulates it. A small, flexible steel arm is connected with the rivet, and in this way establishes a permanent contact between the pile and metallic rod. On another hand, the hook from which the watch is suspended establishes the second communication. It will be seen from this that every time the hour hand of the watch touches the rod fixed beneath the crystal, a communication is at once set up, and the bell rings. A small commutator on top of the stand permits of changing the course of the current and of actuating the bell within, or another one located at any distance whatever in the house, and connected with the chronophone simply by two wires that start from terminals near the commutator.

The apparatus is rendered complete by two small electric buttons designed for directly actuating either the bell in the watch stand or one at a distance.

This ingenious application of electricity is well conceived. The apparatus serves at once as an alarm and a watch stand. It can be used as a bell to call a servant, or for awakening either master or domestic at any hour of the morning for which it has been set on retiring at night, and it can be used for ringing in any part of the house without the necessity of having another pile.

The second apparatus (Fig. 2) that we shall call attention to is an electric lighter constructed by Mr. Delforge. This does not differ in principle from others that we have described, but it is beautifully made, and has the merit of being portable. It consists of a small varnished, black, wooden box which may be carried by

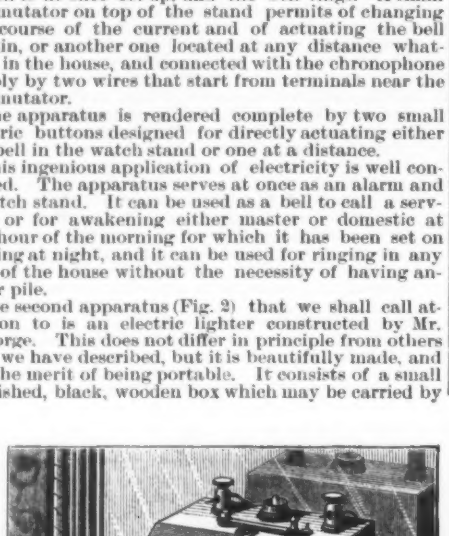


FIG. 1.—ELECTRIC ALARM WATCH.

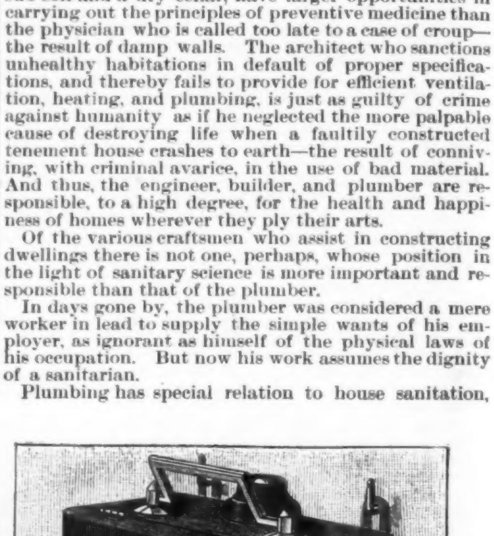


FIG. 2.—ELECTRIC LIGHTER.

means of a handle or be fixed to a wall by means of hooks, and which contains two Leclanche couples. A commutator button on top permits of closing the circuit, and of bringing to incandescence a spiral of fine platinum wire which lights the wick of a small naphtha lamp beneath it. When the platinum spiral is destroyed, it may be easily replaced from a supply kept in the box.—*La Nature.*

THE PLUMBER AS A SANITARIAN.

By WILLIAM HALLEY, Columbus, O.

SINCE self-preservation is an instinctive law of human nature, the observance of sanitary regulations should be the cardinal rule of conduct. In theory this is admitted, but in practice the rule is more conspicuous for its neglect than for its observance. Every one concedes the fact that health interests are paramount to all others, yet they are the last to receive attention. In this wonderful age of material development and scientific advance, all art and philosophy, it would seem, have reached the acme of perfection; yet the science of healthy homes and healthy living has only begun to receive the attention of intellectual people.

At last it is understood that prevention is better than cure, safer and cheaper; that a knowledge of physiology and hygiene is more important than a knowledge of materia medica; that it is better to observe health laws than to submit to the laws of disease; that many diseases are avoidable.

In ancient times, the ravages of epidemic diseases were thought to be the work of the gods. In the days of the Esculapian temples, the office of physician was linked to that of the priest. Both the body and soul of man were held in bondage at the caprice of the gods. Traditional influences still cling to the credulity and practice of modern times. Many people still think that some inscrutable fate stands in a causative relation to the duration of human life. Thus God, instead of unsanitary environments, is held responsible for the terrible devastations of disease and death. "The faith cure" is consistent with this view as to the origin and progress of disease.

There are laws governing both health and disease. When the masses learn that a mysterious fatality is not responsible for the spread of disease and the decimation of cities; that God should be acquitted on the charge of spreading pestilence and death among the people; that there is much of disease due to unsanitary environment and living, then will they take counsel at the shrine of sanitary science.

The medical profession in giving special attention to sanitation has awakened public interest, and accomplished much in stimulating the effort of artisans to an effort for the production of healthy homes. Builders, contractors, architects, engineers, and plumbers are uniting with sanitarians, working shoulder to shoulder with physicians and health boards.

It is with pleasure that I take this opportunity to represent the master plumbers of Columbus in this sanitary organization. A good index to the thoroughness and efficiency of this society is witnessed in the co-operation of various trades and professions in solving the great problem of how to live comfortably and wisely. Every man, of whatever craft, who contributes to the character of buildings and dwellings should be a practical sanitarian.

The construction of a sewer, a vault, or a cellar, as well as the general features of heating, ventilating, and plumbing, involve sanitary questions upon whose solution hinge the health and comfort of the householder. The sewer builder and drain builder who effect a pure sub-soil and a dry cellar, have larger opportunities in carrying out the principles of preventive medicine than the physician who is called too late to a case of croup—the result of damp walls. The architect who sanctions unhealthy habitations in default of proper specifications, and thereby fails to provide for efficient ventilation, heating, and plumbing, is just as guilty of crime against humanity as if he neglected the more palpable cause of destroying life when a faultily constructed tenement house crashes to earth—the result of conniving, with criminal avarice, in the use of bad material. And thus, the engineer, builder, and plumber are responsible, to a high degree, for the health and happiness of homes wherever they ply their arts.

Of the various craftsmen who assist in constructing dwellings there is not one, perhaps, whose position in the light of sanitary science is more important and responsible than that of the plumber.

In days gone by, the plumber was considered a mere worker in lead to supply the simple wants of his employer, as ignorant as himself of the physical laws of his occupation. But now his work assumes the dignity of a sanitarian.

Plumbing has special relation to house sanitation, and should be placed fairly upon its merits. Dr. Derby says: "The well are made sick, and the sick are made worse, for the simple lack of God's pure air and water." The plumber is almost wholly responsible for the supply of these two essential elements, in their native purity, wherever he is employed. Yet it is a fact that there are few avocations in which skillful work is so little appreciated as that of plumbing. People are not interested in the work because it has no reference to ornamentation, and is almost wholly out of sight.

When they appreciate the worth of good plumbing and the baneful effect of that which is bad, they will exercise the same care in the employment of a plumber that is bestowed upon the selection of a lawyer or physician. When they learn how unventilated traps and untrapped waste pipes may become the means of communicating disease, then will the dignity and worth of sanitary plumbing assert itself. Every trap, every pipe, and every closet adjusted gives complexion to house sanitation.

The sanitary plumber is a veritable practitioner of preventive medicine. His work involves the skill of an artist and the technical knowledge of a scientist. Natural laws and physical forces must be mastered at every step. Questions in pneumatics, hydrostatics, chemistry, and hygiene must receive intelligent solution and *application.* The importance of house drainage, as well as its complications and difficulties, increases *pari passu* with the growth of cities and the tendency to metropolitan life. The conditions of healthy living are compromised proportionately with the increase in population.

A city without a perfect system of sewerage—of which house drainage is a unit—would be in as great danger as though it were destitute of a fire department or a police department. A city must be in a sorry plight indeed without sewerage. Think of the vast amount of refuse matter! There is a ton of excreta daily for every thousand inhabitants, and a like proportion for domestic animals. Besides, there are the refuse products of kitchen and stable, and other organic and putrescible matters to be removed by sanitary art or left *in situ* to saturate the soil, contaminate the atmosphere, and poison neighboring wells.

Although a system of sewerage affords a remedy, it must be applied intelligently and skillfully, or the result will be an elongated cesspool and worthless trappings in every house to serve as ventilators, and thus permit sewer gas to escape into living apartments. Much depends upon the plumbing. If it is

perfect, the house is healthy; if imperfect, an unhealthy home is the result. It is easy to be seen that plumbing is the most important feature of a house, to which may be added all the convenience, beauty, and polish of a palace.

But first of all, stamp it with the character of health by sanitary plumbing. Even with the best devices, it is almost impossible to prevent sewer gas at times. Unused fixtures will, in time, permit the water-seal in traps to evaporate. A string or shred of cloth in a trap may act as a siphon. Fixtures are liable to get out of repair. A reckless carpenter may drive a nail into the soil pipe. Rats sometimes gnaw into lead pipes. Traps may become obstructed by the carelessness of servants. There are many accidents by which plumbing work will become crippled and allow gas to escape. Hence it is advisable to exercise extreme care about the location and quantity of plumbing work.

The proper ventilation of pipes and traps is the most essential feature of plumbing. Without ventilation, traps will be siphoned by the suction caused by a flow of water from fixtures above; again, the same downward flow is likely to force the water-seal by increasing the air pressure. Without this ventilation all plumbing is extremely dangerous. It should be remembered that the foulest portion of a sewerage system is that located on private grounds and in dwellings. Any circumstance that favors the ascent of gas and its diffusion through the house should be carefully guarded. However secure the trap in the house-drain may be made, its water-seal is liable to be broken by any event working to compress the sewer air. Wind blowing into the mouth of a sewer may cause sufficient pressure to drive sewer-gas bubbling up through the trap water. A rush of storm water may so lessen the air space in the sewer, and so compress the contained air, as to force the trap. Barring these accidents, the fact that water will transmit aeriform matter, and thus take up sewer-gas and transmit it to the house side of the trap, is to be considered.

If it is desired that living apartments should not ventilate a sewer, these evils must be remedied. I repeat, therefore, that ventilation of plumbing work is the watchword of house sanitation. It is not within the domain of this paper to detail the essential requirements of plumbing; but it is desired to generalize upon a few of the more important principles of house drainage.

All soil-pipe should be continued without change of diameter a few feet above the roof, and, below, deliver into ventilated traps outside the house, so that gas forced back from the sewer need not even depend upon the ventilators at the top, and need not enter the house at all. But this is not sufficient. The waste pipes and traps at various points along the main pipe must likewise be ventilated by separate ventilating pipes taken off close to the sewer side of all traps and joined into a system, if need be, and conducted separately above the roof or conjoined to the soil-pipe *above* the highest fixture. With such a system of ventilation, traps can neither be forced nor siphoned by discharge of water from fixtures. All gas accumulating within drain-pipes is carried off above the house. It is to be remembered, then, that a trap, as the only seal in a house-drain, cannot be depended upon alone to keep foul gas out of the house. It is of imperative importance that there should be a free vent for all gases within the drain-pipe, soil-pipe, or waste-pipes—not into the house, or under its eaves, or near its windows, but above the highest point of the roof. This essential point is attained only by an independent system of free ventilation of all plumbing work. This imposes more material, more work, and more expense. But good plumbing is worth all it costs, while cheap plumbing is, in the long run, extravagant, expensive, and dangerous. This last paves the way to frequent repairs, petty annoyances, foul odors, sickness, doctors' bills, impoverishment, and short life. Sanitary plumbing reduces such evils to a minimum, and is the ounce of prevention where a ton of trouble is pending.

The popular indifference about the nature of plumbing work has caused the plumber to chafe under the abuses imposed. He is considered a dirty laborer, who is supposed to follow the imperious dictates of the architect, owner, and builder in accordance with specifications. A first-class architect will make none other than sanitary specifications for plumbing. Unfortunately for the plumber and for sanitary effect, the architect is too apt to ignore plumbing, giving undue attention to other matters which serve better to display his æsthetic conception. House drainage is made subordinate and subservient to convenience and display. At the last moment it is remembered that the house must be drained, and plumbing specifications are made to fill in the cubby-holes. The contractor is interested in the plumbing only to the point of subcontracting to the lowest bidder after subjecting the plans to cut-rate competition. The plumber is handicapped at every turn. The architect ignores his wants as a sanitary artist; the contractor does not know the value of trapping all fixtures and ventilating all pipes, and so the lowest bidder omits these essential features. The plumber has nothing to do with the specifications, and is not permitted to give his work proper sanitary direction. Being subjected to the thumbscrew of ruinous competition, he must either make a bargain with the devil to put in poor material and scamp work, or allow some conscienceless "scab" to underbid him. Would you know why it is that there is so much poor plumbing done, then consider how plumbers are hampered, instead of being assisted, by all the conditions promotive of sanitary work.

It affords me pleasure to do honor to the Columbus architects in exempting them from the complaints generally urged against their profession. For the most part, our architects are sanitary artists. They consult with the plumber as to the best means and methods of plumbing, and thus produce the most happy effect for the owner and for the public health.

Notwithstanding this green spot in the architectural field, the relation of plumber and architect throughout the country is unsatisfactory and fruitful in evil results.

Mr. James Allison, of Cincinnati, President of the National Association of Master Plumbers, in an address before that society, says upon this point: "An architect is not necessarily a plumber, and is seldom, if ever, practically familiar with the laws of sanitary science, and still less with plumbers' devices, methods, or materials. Yet the plans and specifications of a building are prepared by the architect without consultation with the plumber, who is expected to do the work, and who alone is held responsible for its efficiency, not only by the owner, but also by the public. Let us not be misunderstood here. With the architectural beauty of a building or of the building materials of which it may be composed, the plumber has nothing to do; but with its water and air supplies, its sinks, closets, piping, drainage, and sewerage, he should have everything. It has been customary for the architect to plan a house, arranging the sinks, closets, piping, etc., according to his fancy, without reference to its sanitary correctness, economy, or expediency. The specifications for plumbers' materials refer, for the most part, to their appearance rather than quality, and the expense of a device according to specifications may be made to vary one thousand per cent.

"Some builder will take the whole contract to be executed under the supervision of the architect, according to plans and specifications. The builder sub-lets the plumbing, not to the best, but to the lowest bidder, who, in order to save himself, puts his whole mind on the arts of substitution and how not to do things and still keep within the letter of the specifications. The chief sufferer is, of course, the confiding owner, who, perhaps, finds his costly and magnificent dwelling little better than a 'whited sepulcher.' He spends the rest of his life in repairs and alterations, and is fortunate indeed if he is able to save his family from avoidable sickness and his fortune from the doctors."

What the plumbers want, what the interests of sanitary science demand, is reform in the matter of the *design* and execution of plumbing work. Popular education is one means, legislative enactment is another. Either public sentiment or legislation must force unsanitary plumbing out of existence, else the people must continue to suffer the dire result.

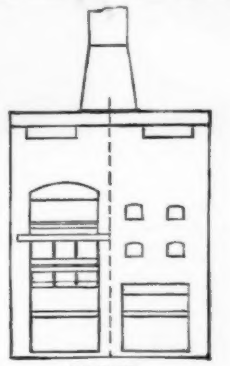
If one-half be true of what is alleged of *bacteria* and the capacity of sewer-gas for their propagation and the spread of disease by them, then plumbing—*sanitary* plumbing—is the most powerful prophylactic agent known, and the plumber one of the most cogent factors of practical sanitation.

Then, in the name of sanitary science, in the name of philanthropy, in the name of disease-stricken homes, I ask this Association to put forth its best endeavors in the promotion of house-drainage, and to secure for its humble representative, the plumber, a recognition—not for his own sake, but for the sake of humanity—among architects, sanitarians, and health boards, and protect the mandates of his practical wisdom by popular education and legislation.—*The Sanitarian.*

CREMATION OF GARBAGE.*

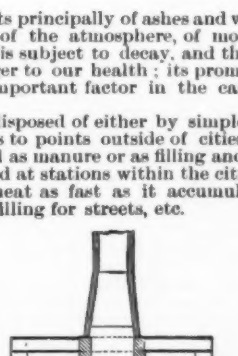
By JOHN ZELLWEGER, C.E.

GARBAGE comprises household and market refuse, and consists of organic and inorganic matter in varying proportions according to the season. The organic matter is of vegetable or animal origin, and the inorganic consists principally of ashes and water. Under the influence of the atmosphere, of moisture, and of heat, garbage is subject to decay, and then becomes a source of danger to our health; its prompt disposal is therefore an important factor in the care for public health.



END VIEWS

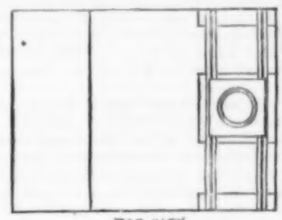
Garbage is disposed of either by simple removal by teams and cars to points outside of cities and towns, and there used as manure or as filling and left to itself, or it is collected at stations within the cities and there destroyed by heat as fast as it accumulates, and the ashes used as filling for streets, etc.



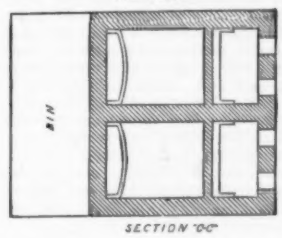
CROSS SECTION

The destruction of the organic portion of garbage is based upon the decomposing effect of heat on the combination of elements contained therein, and upon the affinity of some of these elements for oxygen. The process of destruction is effected in an apparatus designed to expose the charge and the gases emanating therefrom to a high heat and to the contact of hot air. The heat required for this purpose is produced by combustion of garbage with or without additional fuel. For the sake of economy, it is desirable that the process of destruction be self-sustaining—that is, that the heat required be produced by the combustion of the carbon and hydrogen in the organic compounds and in the coke in the ashes.

The problem of destroying garbage by heat, therefore, involves the construction and operation of a furnace that will completely and economically burn great quantities of a fuel containing a large percentage of ashes and water. The capacity of a garbage furnace and the economy of its operation are greatly dependent upon the quantity of an organic admixture to the fuel, and it is therefore indicated either to collect the organic matter as much as possible free from ashes and nonfuel, or to separate it from them by means of screens before charging into the furnace. Water and other liquids should be drained out of the garbage intended for cremation, and can be conveyed under the grate of the furnace, there vaporized, and passed through the incandescent fuel for decomposition. Garbage cannot be completely destroyed by direct charging and burning on an ordinary grate without an excessive use of additional fuel; it requires a systematic treatment and a furnace adapted to the same. The cremation of garbage consists of several distinct processes, which may be classified as follows:

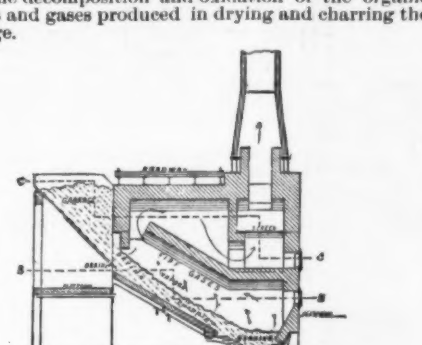


TOP VIEW



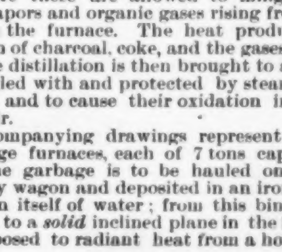
SECTION "CC"

1. The drying of the fresh charge.
2. The destructive distillation of the dry matter.
3. The burning of the remaining charcoal and coke.
4. The decomposition and oxidation of the organic vapors and gases produced in drying and charring the garbage.



These several processes must be carried on separately and in different parts of the furnace, so that the consumption of heat does not interfere with its production. It is essential for the successful cremation of garbage that the full calorific power of the fuel be developed, and all the available heat be transferred to the fire gases before these are allowed to mingle with the aqueous vapors and organic gases rising from the fresh charges in the furnace. The heat produced by the combustion of charcoal, coke, and the gases expelled by destructive distillation is then brought to act upon the gases mingled with and protected by steam, to decompose them and to cause their oxidation in the accompanying air.

The accompanying drawings represent a battery of two garbage furnaces, each of 7 tons capacity for 24 hours. The garbage is to be hauled on top of the furnaces by wagon and deposited in an iron bin, where it can drain itself of water; from this bin it slides by gravity on to a *solid* inclined plane in the furnace, and is here exposed to radiant heat from a hot brick arch



above it, and to the contact of hot fire gases passing over it. When by the action of heat and ventilation the material has become dry, it is pushed down the inclined plane and replaced by a fresh charge. The garbage, on descending the inclined plane, is exposed to higher degrees of heat, and undergoes destructive distillation; the charcoal formed is pushed on to the step grate at the foot of the inclined plane, where it commences to burn, and is finally consumed on the level grate in the bottom of the furnace chamber.

* Read before the Western Society of Engineers, February 2, 1886.

The gases expelled by heat from the dried garbage on the inclined plane ignite with the free oxygen of the surplus air admitted through the grates. The hot fire gases then mingle with the aqueous vapors rising from the fresh charges, and on their way through a secondary fire room above the furnace chamber decompose the organic gases that may be contained in those vapors. Should the heat produced by the combustion of garbage alone not be sufficient, it becomes necessary to spread fine coal (screenings) over the fire through the two doors in the rear of the furnace. Ashes and clinkers found on the grate are pushed directly into suitable wagons placed underneath it.

Back of the fire room and above the furnace chamber is a dust chamber, accessible through two doors, and above this chamber is the chimney flue, provided with a damper for each furnace. The chimney is a brick-lined iron tube, set on top of the furnaces, and stayed sideways.

Assuming that the garbage is deposited in the bin by the scavengers who collected it, and that the ashes and clinkers are hauled off by the same men, it takes but one man to attend to two furnaces, causing an expense of 21 cents per ton of garbage destroyed if no coal is used, and of 36 cents per ton of garbage if 1 ton of screenings is used in each furnace for 24 hours. Since garbage as a rule does not require additional fuel for its destruction, the average cost of the process will not exceed 25 cents per ton. Among the special advantages afforded by a garbage, furnace is the possibility of effectively destroying matter that cannot otherwise be well disposed of, such as infected articles, dead animals, etc. For the destruction of large quantities of garbage the necessary furnace capacity may be provided for either at several separate stations to save haulage, or at one central station to facilitate management and attendance; in the latter case all the furnaces may be connected to one common chimney of large dimensions.—*Trans. Asso. Engineering Societies.*

ON CERTAIN PROPERTIES COMMON TO FLUIDS AND SOLID METALS.*

By Professor W. CHANDLER ROBERTS AUSTEN, F.R.S. Chemist of the Mint, Professor of Metallurgy, Royal School of Mines.

IN one of the beautiful discourses, delivered in the early part of the last century, which grace the annals of the French Academy of Sciences,† Reaumur observes that industrial art, like nature, has its marvels, which we often fail to notice because they are constantly before us.

The extraordinary ductility of metals appeared to him to involve one of the deepest secrets of nature, and although he held that in his time science was hardly in a position to explain more fully than the old philosophers did the cause of this property of bodies, it was nevertheless possible to see better than they what advantage art has gathered from the power of leading and guiding metals by hammering or by traction, and from this point of view, both art and nature seem, he says, to rival each other in furnishing us with remarkable facts. Reaumur, then, with singular clearness, defines the conditions under which metals prove to be ductile.

The relation between the behavior of solid metals and fluids has long been recognized, not merely in the sense that atomic motion is common to solids and fluids, and that therefore "everything moves and nothing remains;" but apart from theory there is much experimental evidence as to the properties that are common to fluids and solid metals, the characteristics of which, at first sight, seem widely separated. Let me remind you of the elementary definition of the two states, *solid* and *liquid*. A solid has a definite external form which either does not change, or only changes with extreme slowness when left to itself, and in order to change this form rapidly, it is necessary to exert a more or less energetic effort. A liquid, on the other hand, can be said to have no form of its own, as it always assumes that of the containing vessel; the mobility of its particles is extreme, its resistance to rupture is very small, and its free surface is always a plane when the mass is left at rest.

Then there is the colloid condition, which intervenes between the liquid and crystalline solid state, extending into both and probably affecting all kinds of solid and liquid matter to a greater or less degree. The colloid or jelly-like body does present a certain amount of resistance to change of shape. Such a substance is well imitated by a skin of thin India-rubber filled with water. Another illustration is probably afforded by iron and other substances which soften under heat, and may be supposed to assume, at the same time, a colloid condition. Lastly, there is the gaseous condition of matter, with which we have but little to do at present.

We are in the habit of regarding metals as typical solids. I hope to trace this evening the analogies of their behavior under certain conditions with that of fluids, and the following list shows the order in which I propose to group the properties common to fluid and solid metals:

1. Rejection of impurities on solidification.
2. Surfusion.
3. Flow under pressure.
4. Changes due to compression.
5. Absorption of gases.
6. Absorption of liquids.
7. Diffusion.
8. Vaporization.
9. Surface tension.

The transition from the liquid to the solid state is marked by the same phenomena, in the case of many metals, as is observed in certain fluids, and I must dwell on this very briefly as leading up to the relations between solid metals and fluids, which come more definitely within the title of the lecture.

Water on passing from the liquid to the solid state undergoes a partial purification, the ice first formed being sensibly more free from coloring matter or suspended particles than the water from which it separates.

Many metals on freezing similarly eject impurities. In the case of alloys, saturated solutions of one metal in another appear to be formed, and excess of metal ejected, a fact which is being studied with much care by my colleague, Dr. Guthrie. The prominent facts are perhaps best illustrated by reference to a frozen mixture of copper, antimony, and lead. The results of some experiments conducted in my laboratory by my assistant, Dr. E. J. Ball, show that when a molten mixture of these metals is solidified, a definite atomic alloy of copper and antimony, which possesses a beautiful violet tint, first forms, and after saturating itself with lead, up to a certain point, it ejects the rest of the lead, driving it to the center of the mass so as to form a sharp line of demarkation, as is shown in the engravings, Fig. 1, the outer circle of which represents violet and the inner gray, presenting a direct analogy to the ice, which is comparatively colorless, first forming from colored water.

Then there is another remarkable analogy between the freezing of certain fluids and the solidification of some metals. Water may, as is well known, be cooled down to $-8°$ Cent. without solidification, but agitation immediately determines the formation of ice, and at the same time a thermometer plunged in the water rises to zero. Faraday stated, in 1858, that fused acetic acid, sulphur, phosphorus, many metals, and many solutions * would exhibit the same effect. Tin also may be cooled to several degrees below its solidifying point without actually freezing, and Dr. Van Riemsdijk, † of Utrecht, has observed that a globule of gold or silver, in a fused state, will pass below its solidifying point without actually solidifying, but the slightest touch with a metallic point will cause the metal to solidify, and the consequent release of its latent heat of fusion is sufficient to raise the globule to the melting point again, as is indicated by a brilliant glow which the button emits, a beautiful effect which I hope to show you.

It may be well also to remind you incidentally that a minute variation in composition is sometimes sufficient to lower the melting point of a metal or alloy, as is instanced by the addition of $\frac{3}{16}$ per cent. of silicon to standard gold, which, as you will observe in the case of this strip of the alloy, softens in the flame of a candle, or at about the melting point of zinc, 412 deg. Cent. although the melting point of standard gold, free from silicon, would be over 1,000 deg. Cent.

Now to pass to solid metals. It is the common experience of us all, that a counterfeit shilling, consisting principally of lead, does not "ring" when thrown on a wooden surface. In 1726, Louis Lemery observed that lead is under certain conditions almost as sonorous as bell metal.‡ He communicated the fact to Reaumur, who, being much struck by it, investigated the conditions under which lead becomes sonorous, and submitted the results to the French Academy.§ He pointed out that in describing a body which is not sonorous, it is usual to say that it is as "dull as lead," an expression which has become proverbial. "Nevertheless," he adds, "under certain conditions lead has a property both novel and remarkable, for it emits surprisingly sharp notes when struck with another piece of lead." He showed that it was necessary that the lead should be formed by casting into a segment of a sphere, that is, mushroom shaped, as in the specimens of lead exhibited. The lead must be free from prominences and must be neatly trimmed. The effect is less marked if the lead be very pure than if ordinary commercial lead be used, but it is only a question of degree.

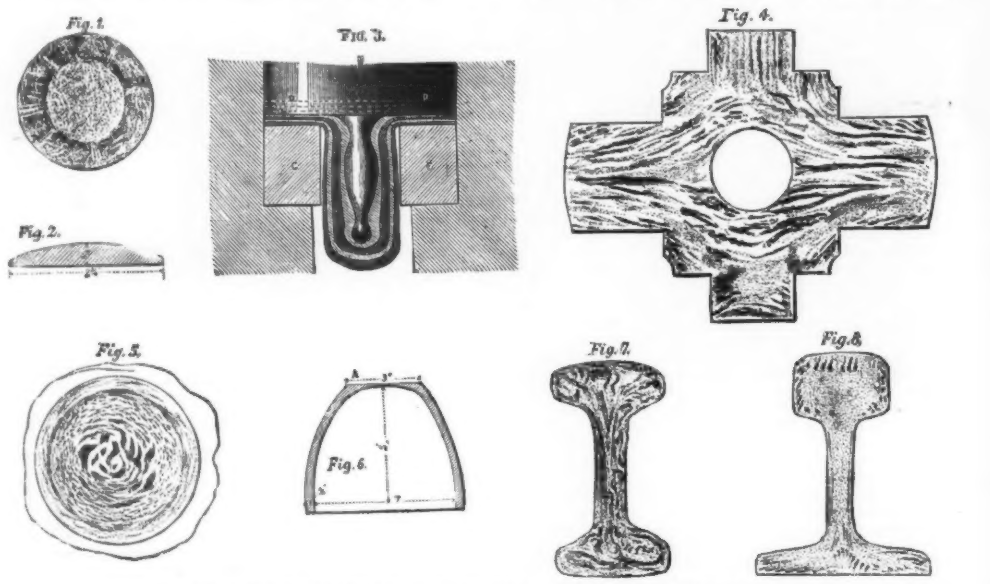
[A mass of pure lead cast into the shape shown in the sketch, Fig. 2, was struck with a piece of lead, and it emitted a sharp, clear note.]

I have shown you the experiment mainly for the sake of being able to quote Reaumur's observations upon it. He showed that the sonorous lead might be rendered dull by hammering it. Here is lead from the same sample of metal as that from which the sonorous mass was cast, but it has been flattened out, and you will observe that it is "dull." I think his remarks have been overlooked in late years. He was led to the belief that in cast lead there must be an arrangement of the interior of the mass which the hammer cannot impart, because lead fashioned by hammering into the same form as the sonorous cast mass is dull; and, more important still, he held that the fibrous and granular structure of the lead is modified in a manner which makes it probable that the sound is due to the shape of the grains, and to the "way in which they touch each other;" further, the blows of the hammer not only change the arrangement of the fibers, but they alter the shape of the grains; "the round grains are rendered flat, they are compelled to elongate and fill the interstitial spaces which previously existed between them. The particles are no longer free to vibrate, hence the lead is dull." These remarks derive additional interest, if we compare them with the observations in Professor Osborne Reynolds' most important lecture on "Dilatancy in Granular Matter," recently delivered here. We shall also, I think, see that this description of Reaumur's shows that he fully appreciated the theoretical importance of the kind of facts depending on the transfer of metallic matter from one position to another, which we now consider to be characteristic of the "flow" of metals; at any rate, I have thought it well to make Lemery's experiment the starting point of the rest of the remarks I have to offer you.

A solid may be very brittle, and may yet, if time be given to it, flow from one point to another. This stick of sealing wax was supported at its ends, and it has in a few weeks bent at the ordinary atmospheric temperature, although at any given point of its flow it would have been easy to snap it with a slight application of force. This much thinner strip of pure lead, of the same breadth as the sealing wax, also bends at the ordinary temperature with its own weight, the ends being supported. Sir William Thomson has pointed out that a gold wire sustaining half the weight which would actually break it, would probably not rupture in a thousand or even a million years, that is to say, there would be no "flow" ending in disruption; if, however, force be suitably applied, metals will flow readily. First let us examine the case of a metal under force applied, so as to compel it to flow through a hole; and I would point to the analogy of an ordinary viscous fluid. This vessel, containing treacle, is provided with a cylindrical hole in its base, and on the removal of the plug which now closes it, the treacle will flow out, the end of the stream being rounded. If a similar vessel be filled with lead, it will, at the ordinary pressure, remain there; but if the pressure be applied, the lead will prove by its behavior that it is really a viscous solid, as it flows readily through the orifice; the end of the jet is rounded, and, as has been shown by the beautiful researches of the late M. Tresca, of Paris,* all the molecules which compose the original block place themselves in the jet absolutely as the molecules of a flowing jet of a viscous fluid would. If the metal has a constant "head," as it would be termed in the case of water, that is, if the vessel be kept filled with solid lead up to a certain level, then you have a continuous stream, the length depending on the constancy with which the "head" and the pressure are maintained. If, on the other hand, the head is diminished so that nearly all the solid lead has been allowed to flow away, you have a folding of the jet, and vertical corrugations, exactly such as would characterize the end of the flow of certain other viscous fluids, and finally the jet forms a distinct funnel-shaped tube, concentric with the jet. It is also seen that when the formation of these cavities takes place, the jet is no longer equal to the full diameter of the orifice, as is shown in Fig. 3, the formation of the contracted vein is manifest, and a new analogy is thus obtained between the flow of solids and liquids.

The application of this fact, that solid metals flow like viscous fluids, is of great importance in industry, and the production of complicated forms by forging or by rolling iron and steel and other metals entirely depends on the flow of the metal when suitably guided by the artificer. The lines of flow in iron may be well shown by polishing a surface of the metal, and by submitting it to the action of a solution of bichloride of mercury, which etches the surface, or, better to the slow action of chromic acid solution, as suggested by Sir Frederick Abel, the result in either case being that any difference in the hardness of the metal, or in the chemical composition, or want of continuity, caused by the presence of traces of entangled slag, reveals the manner in which the metal has flowed. The engravings illustrate the direction of flow in the following cases.

Fig. 4 is a section of a forged crosshead, kindly sent me by Mr. Webb, of Crewe. Fig. 5 represents the top,



PROPERTIES COMMON TO FLUIDS AND SOLID METALS.

* The substance of a lecture delivered at the Royal Institution of Great Britain, on March 26.

† Histoire de l'Academie Royale des Sciences, 1713, p. 199.

* Faraday, Experimental Researches in Chemistry and Physics, p. 379.

† Dr. Van Riemsdijk, Ann. de Chim. et de Phys., t. xx., 1880, p. 66.

‡ Hoefer, Histoire de la Chimie, t. ii., p. 374.

§ Histoire de l'Academie Royale des Sciences, Annee 1726, p. 243.

* These researches extend through a long series of memoirs; those relating to the flow of metals are well summarized in the Proc. Inst. Mech. Engineers, 1867, page 114, and in the report of the Science Conferences held in connection with the Loan Collection of Scientific Apparatus (Physics and Mechanics), London, 1876, page 252.

planed and etched, of a hemisphere of mild steel, of the form and dimensions shown in the sectional view, Fig. 6, ⅝ in. thick, "dished" cold by forcing a plate through a circular orifice. The convolutions of the etched portions afford evidence of the struggle sustained by the flowing particles of the metal. The experiments of M. Tresca were not made on "cinder-free" metal; it is therefore interesting to compare the etched section of the old rail, Fig. 7, the result of the complicated welding of puddled iron, with a basic-Bessemer rail, rolled from steel which has been cast, and which is therefore free from entangled slag. Fig. 8 represents a section of such a rail presented to me by Mr. P. C. Gilchrist.

A very striking illustration of the importance of the flow of metals, when used in construction, is afforded by some observations of Mr. B. Baker, in a recent paper on the Forth Bridge.*

He says: "If the thing were practicable, what I should choose as the material for the compression members of a bridge would be 34 to 37 ton steel which had been previously squeezed endwise, in the direction of the stress, to a pressure of about 45 tons per square inch, the steel plates being held in suitable frames to prevent distortion." He adds: "My experiments have proved that 37 ton steel so treated will carry as a column as much load as 70 ton steel in the state in which it leaves the rolls, that is to say, not previously pressed endwise. . . . At least one-half of the 42,000 tons of steel in the Forth Bridge is in compression, and the same proportion holds good in most bridges, so the importance of gaining an increased resistance of 60 per cent. without any sacrifice in the facility of working, and safety, belonging to a highly ductile material can hardly be exaggerated." I need not point to the extreme interest of these remarks in connection with my subject.

The very ancient mechanical art of striking coin is wholly dependent on the flow of metals. There is a popular belief that the impression imparted to disks of metal during coinage is merely the result of a permanent compression of the metal of which the disk is made. Striking a coin, however, presents a case of moulding a plastic metal, and of the true flow of metal under pressure, into the sunk portions of the die. I once heard Mr. Ruskin say: "You stamp the figure of the cow on a pat of butter; why do you not impress the bee on honey?" Simply because honey is not plastic and is too viscous, and it flows at the ordinary atmospheric pressure. This medal, struck from a series of disks, will serve to show, when the disks are separated, the way the metal flows into the deepest portion of the die.

If the alloy used be too hard, or if the thickness of the metal required to flow be insufficient, the impression will always be defective, no matter how many blows may be given by the press. In Mr. Browning's well-known poem, "The Ring and the Book," there is a subtile recognition of the viscous nature of very pure gold, which he characterizes as "the oozing of the mine;" while, with regard to the manufacture of the ring, he shows:

> "Since hammer needs must widen out the round
> And file emboss it fine with lily flowers,"

that this is only possible because gold behaves like the honey to which he compares it. I have chosen this reference to Browning because I happen to have a coin of "the great Twelfth Innocent," the Pope of the poem I have cited, and this coin has scars on its surface which prove that there was not quite enough metal to flow into the depths of the die.

If one side of a coin be ground away so as to leave a flat surface, and if the disk be then struck between plain polished dies surrounded by a steel collar so as to prevent the escape of the metal, the impression on the disk will be driven through the thickness of the metal, and will then appear on both sides. In industrial art the property of flow of metals is very important. The "spinning" of articles in pewter is a familiar instance, and one which I propose to illustrate.

* Jour. Iron and Steel Inst., vol. ii., 1885, p. 497.

[A disk of pewter was spun, on a lathe, into a vase, the shadow being projected on the screen during the operation.]

The production of complicated forms, like a jelly mould, from a single sheet of copper under the combined drawing and compressing action of the hammer, is a still more remarkable case.

The flow of metals is illustrated very curiously in one phase of Japanese art metal work, of which, however, it is now so difficult to obtain native examples that I have been obliged to prepare, with the aid of skillful artificers in the Mint, the few specimens I have to submit to you. I allude to the metal work in banded alloys to which the Japanese give the name of Moku-me, or "wood-grain." In its preparation thin layers of copper, precious metals, and various alloys are soldered in superposition like the leaves of a book; through these layers, as is shown in Fig. 9, holes are drilled to varying depths in the thickness of the metal, or trenches are cut in it. The mass is then hammered flat until the holes or trenches disappear, and the result is contorted bands, of some complexity, and often possessing much beauty, especially when the color of the metal is developed by suitable chemical treatment and polishing. A similar effect may be produced by beating up the metal from one side and filing the other flat, as is shown in Fig. 10. The structure depends on the flow of the respective metals of which the mass is composed and the behavior of the components of the system, and suggests one of the most marked facts in experimental hydrodynamics, namely, the difference in the way in which water flows along contracting and expanding channels. The sinuous lines the metal assumes in the preparation of Moku-me resemble the beautiful illustrations devised by Professor Osborne Reynolds to show the flow of water.

We have hitherto only considered the flow of metals when submitted to compression. Let us now examine the effect of traction. When a viscous metal, such as iron or soft steel, is submitted to stress by pulling its ends in opposite directions, it stretches uniformly throughout its length; there is in such a solid, a limit in the application of the stress up to which the metal, if released, will return to its normal length; this point is the limit of elasticity. Directly, however, this limit is reached, the metal begins to stretch, and at first it stretches in a very singular way, without an increase of load, as is shown by the curve, Fig. 11; when the limit of elasticity has been passed, the metal continues to stretch with increased load until it gives up resisting and breaks.

The limit of elasticity of a solid body marks the moment at which the body begins to "flow" under the influence of the force to which it is submitted. There are many materials which do not stretch when their limit of elasticity is reached; in very hard steel, for instance, the breaking point and the limit of elasticity practically coincide. Further, it must be observed that very minute variation in composition is sufficient to change the property of a body, and to cause what was a viscous body to break close to the limit of elasticity. A most remarkable instance is presented by certain alloys of gold and copper.

Standard gold, such as is employed for British gold coin, which contains 9,167 parts of gold in 10,000 parts, breaks with a load of 18 tons to the square inch. Its limit of elasticity is reached at 1¾ tons per square inch, but it elongates 34 per cent. before it breaks. If this standard gold has only the $\frac{1}{2000}$ part of lead added to it, it becomes very brittle, and breaks, as is shown by the diagram, Fig. 12, with a stress of about 5⅓ tons to the square inch, instead of 18 tons borne by the original pure standard gold, and as it does not elongate sensibly it cannot be said to flow at all. A remarkable difference in the property of the alloy, standard gold, is therefore caused by the addition of only the $\frac{1}{2000}$ part of lead.

In order to understand this, it will be necessary to trace the analogy between fluids and solid metals still further, and to ascertain what takes place when metals, in a roughly granular state, are submitted to compression, under conditions in which the escape of the compressed metal is, as far as possible, restrained. I must, therefore, turn to what I believe to be the most important work relative to the molecular constitution of metals which has been done for many years, namely, the researches of Professor Walthere Spring, of the University of Liege, whose labors have since 1878 been devoted to the study of the effect of compression on various bodies.* The particles of a metallic powder left to itself at the ordinary atmospheric pressure will not unite; by "augmenting the number of points of contact in a powder," the result may be very different. The powders of metals may weld into coherent blocks. Let us appeal to his own experiments. The section, Fig. 13, shows the general form of the compression apparatus employed by Spring.

Under a pressure of 2,000 atmospheres on the piston, or 13 tons to the square inch, lead in the form of filings becomes compressed into a solid block, in which it is impossible to detect the slightest vestige of the original grains, so that lead filings weld into a block identical with that obtained by fusion. Under a pressure of 5,000 atmospheres the lead no longer resists the pressure, but flows as if it were liquid through the cracks of the apparatus, and the piston of the compressor descends to the base of the cylindrical hole, driving the "flowing" lead before it.

This result in the case of lead is hardly unexpected.† Bolley showed, in 1849, that lead prepared in a particular way, so as to be in a state of fine division, may be converted under a powerful press into a flexible plate, or may be made to receive a sharp impression. The more interesting results were obtained by Spring with crystalline metals. Bismuth is, as is well known, very brittle and crystalline, yet fine powder of bismuth unites under a pressure of 6,000 atmospheres into a block very similar to that obtained by fusion, having a crystalline fracture. The density of compressed bismuth is 9·89, identical with that of metal which has been fused. The table shows the amount of pressure required to unite the powders of the respective metals:

	Tons per Square inch.
Lead unites at	13
Tin "	19
Zinc "	38
Antimony unites at	38
Aluminum "	38
Bismuth "	38
Copper "	33
Lead flows at	33
Tin "	47

We will endeavor to repeat M. Spring's results in the case of bismuth. It is necessary that the powder be perfectly clean and dry; if it be then submitted *in vacuo* to a pressure of 6,000 atmospheres, it will weld into a crystalline mass.

We know that combinations are produced when certain bodies in solution are submitted to each other's action. But do solids combine? Is the alchemical aphorism, that bodies do not react unless they are in solution, true? Experiment proves that such solution is not necessary. I have here two anhydrous salts, iodide of potassium and corrosive sublimate, and they are at the same time dry; when they are mixed in this mortar, they unite, as is shown by the vermilion color which is produced.

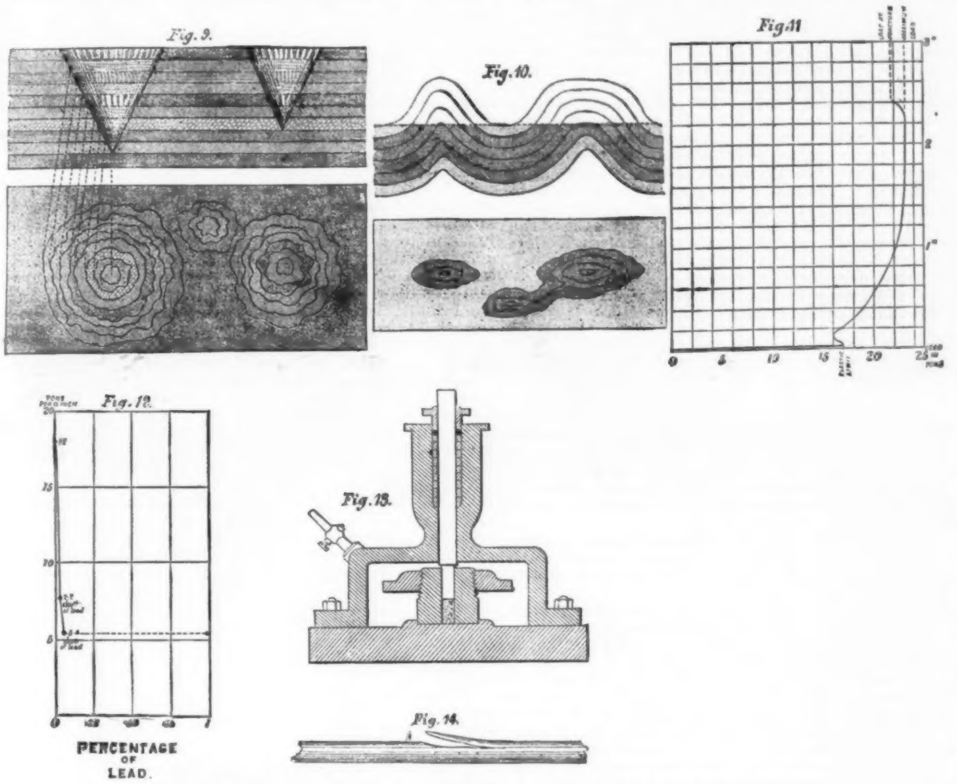
My colleague, Professor Thorpe, called attention to the importance of this fact at the meeting of the British Association at York, 1881. But do solid metals combine in the sense, that is, in which chemical combination is possible between metals, when submitted to each other's action? We know that metals do combine if they be fluid, and the extraction of gold and silver from their ores by amalgamation is moreover easy.

It occurred to M. Spring that if there be a true union between the particles of a metallic powder, when submitted to great pressure, it ought to be possible to build up alloys by compressing the powders of their constituent metals, and he urged that the formation of alloys by pressure would afford the most conclusive proof that there is a true union between the particles of metals in the cold, when they are brought into intimate contact. Experiment proved that this reasoning was correct, for by compressing, in a finely divided state, fifteen parts of bismuth, eight parts of lead, four parts of tin, and three parts of cadmium, an alloy is produced which fuses at 100 deg. Cent. It is necessary, however, to compress the mixed powders twice, crushing or filling up the block obtained in the first compression, because the mechanical mixture of the constituent metals is not sufficiently intimate to enable a uniform alloy to be obtained by a single compression. The alloy we have thus produced fuses, you will observe, in boiling water actually at 98 deg. Cent., although the melting point of the most fusible of its constituents, the tin, is 228 deg. Cent. I agree with Professor Spring in thinking that the formation of alloys by pressure affords the most complete proof which can be given of the accuracy of the views he has adduced.

The formation of fusible metal by compression leads me to deal with an objection which may, no doubt, have suggested itself to many of us. It may be urged that by compressing these metallic powders heat is evolved, and that this heat may be sufficient to produce incipient fusion in the metallic powders, or, at all events, may exert a material influence on the result obtained. This objection has been experimentally anticipated by Professor Spring. First, the compression is effected with extreme slowness, and therefore there can be no question as to the sudden evolution of heat, as would be the case if the powders were compressed by impact instead of by a slow squeeze; and to sum the matter up briefly, Spring calculates, taking an extreme case, that if it be granted that all the work done in compressing the powders were actually translated into heat, it would only serve to heat a cylinder of iron 10 mm. in height and 8 mm. in diameter (the dimensions of cylinder produced in his apparatus) 40·64 deg. Cent. In order that direct experimental evidence might not be wanting, Spring took the organic body phorone, a

* Bull. de l'Acad. Royale de Belgique [2] t. xlv., No. 6, 1878. [2] t. xlix., No. 5, 1880. See also subsequent papers in the same publication, in the Bull. Soc. Chim., Paris, and in the Deutschen Chemischen Gesellschaft (Bildung von Legirungen durch Druck), b. xv., p. 595.

† Leibig u. Kopp. Jahresbuch, 1849, p. 278, quoted by Dr. Percy, Metallurgy of Lead, 1870, p. 9.



PROPERTIES COMMON TO FLUIDS AND SOLID METALS.

hard, crystalline substance, which melts at 28 deg. Cent., and compressed it exactly as in the case of the metallic powders.*

He took the precaution to place a shot of lead on the top of the powder before submitting it to compression; only imperfect union of the particles of the phorone resulted.

The conclusion of the experiment proved that the shot remained where it had been placed at the top of the column, and therefore the 28 deg. necessary to melt the substance had not been evolved, for if it had, the shot must have fallen through the fluid mass. I think, then, it is absolutely safe to conclude that, in the compression of bismuth, for instance, there can be no question of the evolution of the heat necessary for the fusion of the metal. There is, however, other evidence to which I may incidentally appeal.

M. Spring has shown that by compressing powders together, chemical combination may be induced, and he has, in this way, produced arsenide and sulphide of zinc, sulphide of lead and of bismuth, and arsenide of lead. These are not merely intimate mechanical mixtures. Take, for instance, the sulphide of magnesium produced by compression; it is soluble in hot water; treatment with dilute hydrochloric acid evolves sulphureted hydrogen, which is not the case with mere mixtures of magnesium and sulphur. Further, Spring has shown that by pressure a body may be made to pass from one allotropic state to another. Plastic sulphur is, under a pressure of 6,000 atmospheres, compelled to pass into the condition of octahedral sulphur, an allotropic state which possesses a greater density. And he points out that a solid metal (not powders of metals) may have cavities obliterated by pressure, but that matter cannot be permanently compressed by pressure, unless it can assume an allotropic state of greater density than the one it possesses at the moment of compression.†

Now let me point to the evidence these experiments afford as to the relation between solid metals and fluids. Members of the Royal Institution will know that Faraday discovered, in 1850, that two fragments of ice pressed against each other will unite, tendency to their union being considerable when the fragments are near their melting point. We also know what splendid service the regelation of ice has afforded in the hands of Dr. Tyndall, in explaining the formation of glaciers.

Ice owes its movement, not to viscosity, but to regelation, and the union of fragments of ice under compression is due to regelation. The facts which have been appealed to, and the theories which have been formed, respecting the regelation of ice, are too well known to you to demand lengthy notice from me. I will only observe that bismuth, like ice, expands on solidifying; and although Faraday failed to establish the existence of a property similar to regelation in bismuth, an eminent engineer, Mr. Thomas Wrightson, to whom we owe a series of experiments on the fluid density of metals, has satisfied himself by experimental evidence that regelation exists in bismuth. Now, in explaining Spring's results, we are met by this difficulty: the union of the particles of the metals cannot, in all cases, be due to viscosity, because viscous bodies are always capable of being stretched, and we find the welding taking place between the compressed powders of bodies such as zinc and bismuth, which, when submitted to traction, will not stretch. Spring therefore asks, "Is it possible that regelation may have something to do with the union of the powders?" and he urges, "Is it safe to conclude that regelation is peculiar to water alone?" "It is difficult to believe," he adds, "that in the large number of substances which nature presents to us, but one exists possessing a property of which we can find only minute traces in other bodies. The sum of our chemical and physical knowledge is against such a belief, and therefore the phenomenon of regelation may be pronounced in ice without being absolutely wanting in other bodies. To ascertain whether this is so, it is necessary to submit various bodies to the conditions under which the phenomena can be produced." "What," he asks, "are these conditions?" and he answers, "The pressure supported by the body, a certain degree of temperature, and time."

Helmholtz and Tyndall have shown that when the pressure is weak, the regelation of ice is effected slowly. Spring points out that nitrate of sodium and phosphate of sodium, in powder, left to themselves in bottles become coherent, and if the coherence in these and other chemical compounds is but weak, it is simply because the points of contact between the particles of powder are but few.

If, on the other hand, metallic or other powder be submitted to strong compression, the spaces between the fragments become filled with the *debris* of the crushed particles, and a solid block is the result. Finally, it may be urged that this union of powders of solid metals under the influence of pressure, that is to say, the close approximation of the particles, can be compared to the liquefaction of gases by pressure.

At the first view this comparison may appear rash or strained, but it is nothing if we accept the views of Clausius on the nature of gases and liquids. In a gas the molecules are free, but if by pressure at a suitable temperature the molecules are brought within the limits of their mutual attraction, the gas may be liquefied, and under suitable thermal conditions solidified. The mechanical pulverization of a metal merely detaches groups of molecules from other groups, because the mechanical treatment is imperfect, but the analogy between the solid and a gas has, in a sense, been established; filing has coarsely gasified the mass, but pressure will solidify it, as you have already seen.

It is possible that in some of these metallic blocks, the particles are not actually united by the pressure, which may, nevertheless, develop the kind of "mutual attraction" contemplated by Sir W. Thomson as existing between two pieces of matter at distances of less than ten micro-millimeters.

There are two other properties which solid metals possess, in common with certain fluids, to which I must briefly allude. The first is the power of dissolving gas, which metals in the solid colloid condition possess. I will not offer any experimental illustration on this point, because the work of Graham has been fully

* Bull. Soc. Chim., Paris, 1884, t. xli., page 488.

† "Sur l'elasticite parfaite des corps solides chemiquement definis." Bull. Acad. Roy. Belgique [3], t. vi., 1883.

dealt with in this theater by Dr. Odling; and I have, in a course of lectures recently delivered here, shown that just as solid palladium occludes hydrogen, so the alloy of rhodium and lead occludes oxide of nitrogen, which it gives up with explosive violence on heating *in vacuo*, suggesting an analogy with fluid nitro-glycerine. The last property I have to submit to you is the power which certain solid metals possess of taking up fluids, sometimes with a rapidity which suggests the miscibility of ordinary fluid substances.

In reference to this I have found an interesting paper published so long ago as 1713, by the Dutch chemist Homberg,* "On substances which penetrate and which pass through metals without melting them." He enumerates several substances which will pass through the pores of metals without disturbing the particles, and he points out that mercury penetrates metals without destroying them. Few of us are, I think, familiar with the rapidity with which mercury will pass through tin. Here is a bar, 1 in. wide and ⅛ in. thick; if a little mercury be rubbed lightly on it, the mercury will in thirty seconds penetrate the mass, so that it breaks readily, although before the addition of the mercury, the bar would bend double without any sign of fracture.

With regard to the vaporization of solid metals, time will only permit me to remind you that Demarcay† has shown that *in vacuo* metals evaporate at much lower temperatures than they do at the ordinary atmospheric pressure, and he suggests that even metals of the platinum group will be found to be volatile at comparatively low temperatures. Merget‡ has shown that the solidification of mercury by extreme cold does not prevent the solid metal evaporating into the atmosphere surrounding it.

With regard to the remaining properties on my list, you will say, Surely, solid metals do not show any tendency to diffusion? I have shown§ that in the case of molten metals the interdiffusion may be extremely rapid, but, with regard to solid metals, some experiments conducted by Sir Frederick Abel prove that carbon can pass from a plate of richly carburized iron to one of iron free from carbon, against which it is tightly pressed. This passage of carbon takes place at the ordinary temperature, and it is difficult to explain the transference of matter without admitting the presence of some action closely allied to the diffusion of liquids.

Finally, can we offer any evidence of surface tension in solid metals? There is only one experiment to submit to you illustrating a point I am still investigating. Some months since, Mr. F. W. Fletcher, manager of the works of Messrs. C. Ash & Sons, the well-known dealers in the precious metals, pointed out to me an interesting property of a hard-drawn rod or thick wire of 13 carat gold; the gold being alloyed with silver or copper in the following proportions:

Gold	54·17
Copper	33·33
Silver	12·50
	100·00

If such a rod be touched with a solution of chloride of iron or certain other soluble chlorides, it will, in a short time, varying from a few seconds to some minutes, break away, as is shown in the diagram, Fig. 14, the fracture rapidly extending for a distance of some inches.

[The image of the rod was projected on the screen, and in a few seconds after the rod was touched with chloride of iron, it split close to the point of contact with the solution.]

This result may be attended with the absorption of gas, but, in any case, it would appear that in the hard-drawn rod the surface is in a state of tension, which is released by the action of the chloride.

The facts we have considered afford additional evidence as to continuity in the properties of all kinds of matter, and serve as a connecting link with the work of the past, the importance of which is too often overlooked. I trust it will be evident that the analogy of solid metals to fluids has an important bearing on the labors of those who are striving to advance science, to develop art, or to promote the industrial well-being of this country.

GOSSYPIN.

THE COLORING PRINCIPLE OF COTTON SEED.

THE quantity of cotton seed annually crushed and pressed for oil in the United States probably equals two and three-quarter millions of tons, and if we add to this the half million tons similarly treated in Europe, the proportions of this giant infant industry begin to appear. As expressed, the oil is of an intense ruby color, sometimes verging to black, owing to its containing in solution a powerful vegetable coloring principle, properly termed gossypin. This peculiarity distinguishes it from all other oils. The oil cells appear in the seeds as brown specks dispersed through the albuminous matter. According to Mr. James Longmore, of the Liverpool section of the Society of Chemical Industry, who has given great attention to the subject, the quantity of coloring matter in a ton of crude oil is fifteen pounds, although this proportion must vary considerably. The woody husk of the seed also contains a large quantity apparently of the same nature. Its properties are insolubility in acids, slight solubility in water, free solubility in alcohol or alkalies. In its dry state it is a light powder of a pungent odor, of a brown color, and strongly tinctorial.

For expression, the seeds are first crushed by passing through rollers, and then ground to a fine state of division under edge wheels. When sufficiently reduced, the powder is transferred to steam-jacketed kettles, and heated for about ten minutes to a temperature sufficient to render the oil more easily expressible, and to coagulate the albumen of the seed. From the kettles the hot and finely ground seed is put in coarse bags, each making a cake weighing about ten pounds, and subjected to powerful hydraulic pressure. The crude, nearly black oil, containing the coloring matter in solution, is by this means expressed, and runs into a tank from which it is transferred to the refinery. The next

* Mem. de l'Acad. Royale des Sciences, 1713, p. 306.

† Comptes Rendus, xcv., p. 183 [1882].

‡ Ann. de Chim. et de Phys. [4], xxv., 121.

§ Report British Association, 1883, p. 402.

step is the removal of the coloring matter, the process bringing the oil to a light straw or yellow tint.

The tank used is of iron; it is provided with a mechanical agitator, and its capacity sufficiently exceeds that of the charge of 10 tons weight of crude oil and 30 cwt. caustic soda lye of 10° to 12° Twaddell. The lye, at the temperature of 60° F., is fed slowly by perforated pipes extending over the surface of the oil and distributing uniformly. As the agitation proceeds, the lye and oil, which are both cool, mix, and the latter gradually becomes full of black flocculent particles of soap caused by the partial saponification of a portion of the oil by the caustic soda lye. The agitation is continued for about half an hour, and at the end of that time a portion is taken out and allowed to stand. If the soapy particles precipitate, and the oil is found nearly deprived of color, the operation is then terminated. If not, the agitation is continued, more lye being added until the desired decoloration is obtained. The charge of oil is then allowed to stand for twelve or fifteen hours, until the "mucilage" or partially saponified portion of the oil, with the liquid excess of lye used, has settled away. The clear oil is then run off, and the refining completed by washing and bleaching.

The success of this process evidently depends on the property the coloring matter possesses of solubility in alkalies. The particles of soap seem to be sufficiently alkaline at the moment of forming to inclose within them the coloring matter, which is thus precipitated from the rest of the oil. After separation the precipitate is treated with strong soda lye, say 70° Twaddell, and heated. The coloring matter is thus dissolved out, the solution carefully filtered from the saponaceous mass, and dilute sulphuric acid gradually added to the filtrate until the alkali is completely neutralized. The gossypin then separates as a flocculent precipitate. This is collected on a filter, carefully washed to remove any trace of acid, and dried slowly at a low temperature. It is then ready for use as a dye, and gives fast colors on both wool and silk. The saponaceous mass, partially decolorized by the caustic soda lye, may either be converted into hard soap, or, by addition of milk of lime, be deprived of any albuminous matter, be bleached with chlorinated lime (chloride of lime), and by treatment with a mineral acid, the refined oil mingled with fatty acids obtained.

To dye wool with gossypin, take for every ten pounds of yarn seven ounces of the dye dissolved with seven ounces of soda crystals in sufficient water, and boil for three hours. Another method is to prepare the bath by dissolving the gossypin with the requisite amount of soda crystals, and then precipitate it with just the quantity of sulphuric, hydrochloric, or acetic acid necessary to render the solution neutral. The coloring matter remains in suspension in a very fine state of division. In this state it is taken up by the wool immediately. The operation is shortened, but the wool is liable to be surface-dyed only, and in the operation of scouring the shade will be much lightened. No more sodium carbonate should be used than is absolutely necessary to dissolve the dye, as the attraction of the alkali neutralizes the attraction of the wool for the coloring matter. A richer shade is obtained by using wool previously mordanted in the usual manner by working in a bath of potassium bichromate; this deepens the shade, giving a warm brownish-red.

The shades and colors can be varied to any extent by combinations with other coloring matters, especially the anilins, with which gossypin seems to possess the property of forming definite compounds, the nature of which has not been fully investigated. These are formed by dissolving equal weights of gossypin and soda crystals in water. To the strained solutions thus obtained add a previously prepared solution of the anilin dye, the strength and quantity of the latter being governed by the shade required. The whole is then thoroughly mixed, and dilute sulphuric acid is slowly poured in until the neutralization is effected. The coloring matters precipitate, and are separated, washed and dried. They are not decomposed by boiling water; they possess much of the brilliancy of the anilin, and of the quality of fastness of vegetable dyes. The proportion of the former required is therefore much reduced.

The methods of dyeing silk are analogous to those described for wool.

If the coloring matter is heated to the boiling point with its own weight of soda crystals and six times its weight of water, the whole being stirred until dissolved, it will on cooling set to a paste, and in this form it is very readily soluble. For some purposes this may be more convenient than the dry powder.

Unless the dyeing be very carefully conducted, a faint feeling of harshness is imparted to the wool. This may be a natural property of the dye; but it is more likely to be due to the alkaline treatment through which it passes in the process of preparation, and will probably yield to further experiment.

CENTENARY OF PARMENTIER.

THE city of Montdidier, where the philosopher Parmentier was born, on the 17th day of August, 1737, has recently celebrated the centenary of one of the most memorable events in the history of useful discovery, that is, the culture of the potato, which has so often been called the "poor man's bread." We, in our turn, also wish to do reverence to a man who signalized himself by the most important services.

It has been said that the potato reached Europe much before Parmentier's time, in the 17th century, and even in the 16th, according to some historians. Mr. Virey has demonstrated that the right of priority belongs to the Spaniards, who, in the first half of the 16th century, were propagating this valuable product of the American soil in their European possessions. This appears to be indisputable. Much has been written upon this subject, but it is nevertheless true that the potato was nearly ignored when Parmentier resolved to cultivate it, and that it is to him at least that our country is indebted for the benefits of it. Parmentier's life was a glorious one, and he consecrated it with rare devotion to the interests of his fellow man. He was an orphan at an early age, and entered a pharmacy as a student before he had finished his studies. In 1757 he went as a hospital steward into the army of Hanover, where he conducted himself with great energy. He was five times made prisoner during the war, and remained a prisoner in Prussia until the end of the campaign.

On returning to Paris, in 1763, he resumed his studies,

and in 1774 succeeded in obtaining, after competitive examination, the situation of pharmacist at the Hôtel des Invalides. It was at this epoch that he began to study the properties of the potato, and that by dint of perseverance he succeeded in overcoming the blind prejudices that were opposed to the use of this valuable plant in France. Parmentier cultivated the tuber in the vicinity of Paris, but the opposition of the masses and of the great was fierce against him. Louis XVI. had the honor of supporting Parmentier's contest against these vain prejudices, and had his troops

FIG. 1.—LOUIS XVI. VISITING PARMENTIER'S POTATO FIELD.

to defend the field of Sablons, where the first potatoes planted in France would have been uprooted by guilty hands had they not been protected. According to some historians, the king, on visiting the field of culture, received the flowers of the potato from Parmentier. This scene has been restored by our artist, Mr. Gilbert, in Fig. 1. The great agriculturist was received at court, and the king, with a potato flower in his button hole, gave him his hand and presented him to queen Marie Antoinette.

Parmentier was not content to devote himself to the potato, but made Indian corn and the chestnut also the objects of his studies; and he said everything possible in favor of these products, which now form the wealth of some of our districts. Ever anxious to increase our food resources, he made a long and remarkable study of bread manufacture, and proposed an economic method of grinding, by means of which the product of the flour is increased by one-sixth. During the revolution Parmentier inspected the salt provisions designed for the navy, and contributed toward rendering practical the manufacture of sea-biscuit—a genuine benefit in the alimentation of the navigator.

Named member of the Institute in 1801, and inspector-general of the health service in 1803, Parmentier never grew tired of devoting himself to useful studies. He improved the army bread, drew up an excellent pharmaceutical code for civil hospitals, and busied himself with recipes for cheap soups.

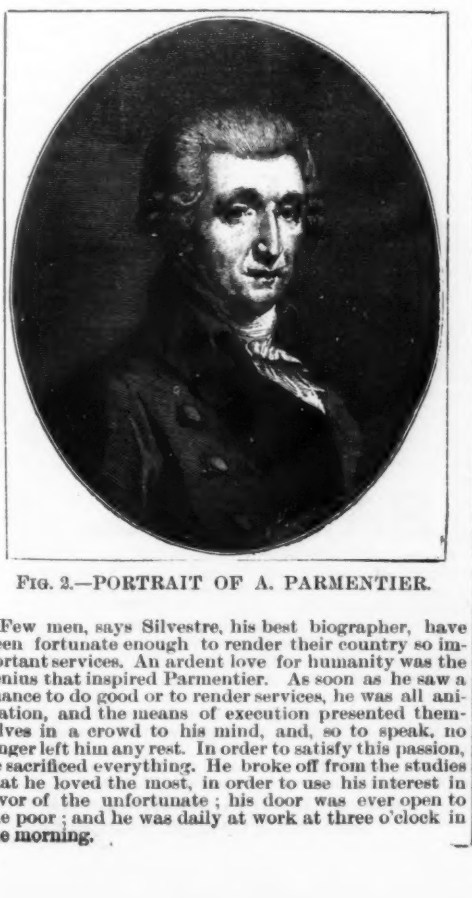


FIG. 2.—PORTRAIT OF A. PARMENTIER.

Few men, says Silvestre, his best biographer, have been fortunate enough to render their country so important services. An ardent love for humanity was the genius that inspired Parmentier. As soon as he saw a chance to do good or to render services, he was all animation, and the means of execution presented themselves in a crowd to his mind, and, so to speak, no longer left him any rest. In order to satisfy this passion, he sacrificed everything. He broke off from the studies that he loved the most, in order to use his interest in favor of the unfortunate; his door was ever open to the poor; and he was daily at work at three o'clock in the morning.

The center of the Montdidier festival was naturally the statue that has been erected to the great inventor in that city. This statue represents the philanthropist dressed in the French fashion, wearing a powdered wig, and holding the immortal flower in his hand. Bass-reliefs are sculptured around the statue, showing the army pharmacist upon a field of battle, the plain of Sablons invaded by marauders, and Louis XVI. decked with a *boutonniere* of potato flowers. The Parmentier centennial festival was kept up during the two weeks following Easter, and ended with a great banquet at which the Ministers of Agriculture and Public Instruction were present.

Parmentier died at Paris on the 13th of December, 1813. He was more than an eminent scientist; he should be regarded as a benefactor to humanity.—*La Nature.*

ON THE APPLICATION OF HUMAN EXCRETA AS MANURE: THE DEPORTMENT OF UREA TOWARD SOILS.

THIS is the result of an experimental investigation carried out at Komaba Agricultural College by Dr. Kellner, Professor of Agricultural Chemistry, Tokio, Japan, with assistance of his pupils. The following is a brief abstract:

"It is a general custom, both in Japan and China, to use human excreta as manure, only in a *highly decomposed state.* The application of fresh excreta is regarded as objectionable, it being said that the plants supplied with them are liable to wilt.

"Having been consulted about this injurious influence, and nothing being known in regard to it, I resorted to a few experimental researches in order to find out its true cause.

"Fresh excreta differ from decomposed ones in a twofold way: on the one hand, the reaction of the former is acid, that of the latter alkaline; and on the other, but connected with the difference of reaction, the fresh urine is rich in urea, while the decomposed one is almost destitute of it, *the urea being converted during putrefaction into ammonium carbonate.*

"All considerations lead to the conclusion that the difference of reaction cannot explain the injuries done by fresh excreta, the acid as well as the alkaline reactions being soon neutralized by common soils. But the urea of fresh urine might in some way interfere with the normal process of vegetable growth.

"Owing to the weak affinities of urea, it was hardly to be expected to enter into chemical combination with the ingredients of soils, while ammonia is usually rapidly absorbed by them, so that the fluids left behind are almost free from it. Our researches have indeed corroborated this opinion: *urea is not absorbed by soils, but totally left in solution.*

"Human urine contains about 2 per cent. of urea, and even when diluted with an equal bulk of water (as farmers do), it still represents so strong a solution that plants cannot live in it. The agricultural plants grow best in nutritive solutions containing ½ to ⅙ part of nutrients per 1,000 parts of water, while the diluted urine as applied in Japan contains still 10 parts of urea per 1,000 parts of water, besides a fair proportion of common salt and sulphates, which are, as we know, likewise not absorbed by soils.

"The injurious effect exerted by too strong nutritive solutions consists, as is commonly known, in preventing or hindering the diffusion of water from the soil into the roots; hence the plants wilt.

"The conversion of urea into ammonium cabonate is accomplished within a few days, as well when the excreta are kept in air as when put into soils. As this process is, however, performed by the lower organisms (bacteria and micrococci), and as the latter can live but near the surface of soils where oxygen is present, it was expected that in a certain depth of the ground urea may not be altered.

"Researches made with every possible precaution to prevent the access of atmospheric germs into the solutions and bottles have indeed shown that, even in the porous soil of Komaba (volcanic ash), *ammonification can be performed only to a depth of 60 centimeters.*

"Urea solutions kept in contact with samples of soil taken from depths of 60 to 65, 120 to 125, 150 to 155 cm. did not contain any trace of ammonia after a lapse of two months, while surface soils (0 to 5 cm.) speedily converted the whole of urea employed, so that after sixteen days no more urea could be found. The next layer, taken from a depth of 25 to 30 cm., accomplished the conversion far more slowly, so that this process was not yet completed after two months.

"Farmers using fresh urine run, consequently, the risk not only of injuring their crops, but also of losing a great deal of the most valuable nitrogenous compound of this manure by rain, which carries the urea into deep sub-soils beyond the reach of the roots of plants.

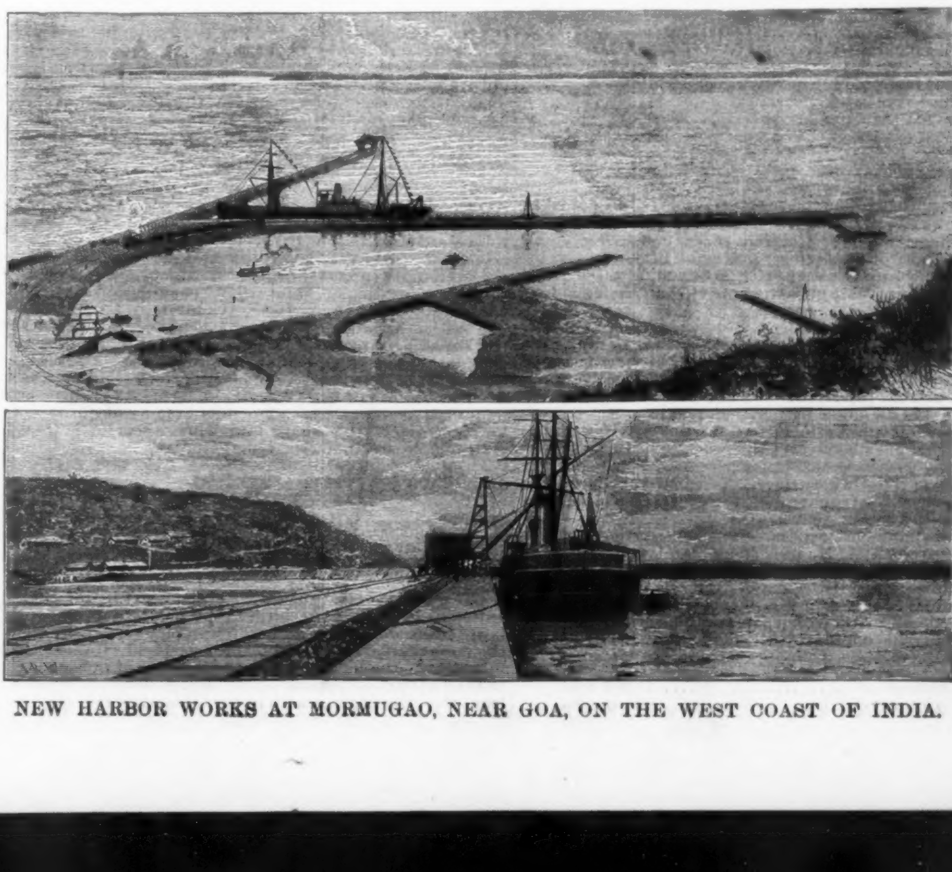
"The results of these researches are valid not only with regard to human excreta, but also, to a certain extent, with reference to the urine of the live stock."

NEW HARBOR ON WEST COAST OF INDIA.

WE are informed that the harbor works at Mormugao, near Goa, on the west coast of India, now under construction by the West of India Portuguese Guaranteed Railway Company, have so far advanced that the steamship Westbourne, drawing 23 ft. of water, and with 2,700 tons of cargo and coal on board, was able to steam alongside the quay wall, inside the breakwater, on April 15 last; and to discharge heavy lifts of machinery and other cargo.

We present two illustrations of the harbor and the ship lying there. The space between the spectator and the quay, shown in our first illustration, is in course of being reclaimed for wharfage accommodation. There is a model of the breakwater in the Colonial and Indian Exhibition. It is worthy of remark that vessels will be able to enter the harbor of Mormugao, and to lie alongside the quay wall, within one hour after leaving the open sea; which cannot be done at any other harbor in India, from Bombay to Calcutta, including Ceylon. At Bombay, vessels have to be taken into dock; and at Calcutta, before reaching the wharves, they have to go through the intricate navigation of the Hooghly.

Mormugao is about two hundred and fifty miles south of Bombay, in the Portuguese territory, which extends sixty-three miles along the Malabar coast, and



NEW HARBOR WORKS AT MORMUGAO, NEAR GOA, ON THE WEST COAST OF INDIA.

is bounded inland by the Bombay Presidency of British India. The two adjacent inlets of Mormugao Bay and Agoada Bay, with the estuaries of the rivers there discharging their waters into the sea, afford commodious harbors. The ancient Portuguese city of Goa, famed for the splendor of its churches, lies on the northern side of the river Raichol, near Panjim, or Nova Goa, the residence of the Governor-General of Portuguese India; and Mormugao, which lies to the south, and has hitherto been little more than a village, will no doubt, in view of the extended traffic which is likely to be developed there, become a considerable town.

Plans are under the consideration of the Portuguese Government, who have shown every disposition to favor the undertaking, which, it is believed, will restore prosperity to that portion of the Portuguese dominions. His Excellency Senor Francisco de Amaral, who arrived in India last April, on his appointment as Governor-General of Goa, is a distinguished Portuguese gentleman of most enlightened views; he took an early opportunity of visiting the works in person, and expressed the great interest he felt in their success. The works were begun toward the end of 1881, and will be sufficiently advanced to be open for traffic at the end of the current year.

The harbor, which will be more readily accessible than any now existing in India, will be connected by about fifty miles of railway, through Portuguese territory, with the Southern Mahratta system of railways, extending from Poona on the north to Mysore on the south, with branches, in all over 1,050 miles in length. There remain, however, several tunnels on the Ghat section of the railway to be completed before through traffic can be carried by rail; but bullock wagons will be utilized until the whole line is ready, which it is expected will be in 1887.—*Illustrated London News.*

DISTRIBUTION OF POWER IN WOOLEN MILL.

As some of our readers may be interested in woolen manufactories, the following analysis of the power actually used in driving a woolen mill in central Ohio is thought worthy of insertion.

The mill building was three stories and basement, with engine and boiler room at one side and dye house at the rear. It was running on cassimeres and flannels with a good, fair average set of machines.

A test of ten hours' work by indicator, with cards taken each fifteen minutes, gave the following average:

Morning from 7 o'clock to noon	69·80 H. P.
Afternoon from 1 o'clock to 6 o'clock	58·47 H. P.

Equal to sixty-four horse power per hour.

Afterward an analytical measurement was made of the power, to determine the proportion of friction work, and also the net power absorbed by each machine, with the following results:

	Horse Power.	
BASEMENT.		
One Sturtevant blower	1·25	
One centrifugal machine	1·00	
Two rotary machines	0·50	
One wool exhauster	0·75	
Four fulling mills	8·00	
Four dry gigs	2·50	
One gray shearer	0·50	14·50
DYE HOUSE.		
One wool washer	0·25	
One centrifugal machine	0·75	
Two wet gigs	1·50	
One washer	1·25	3·75
FIRST FLOOR.		
Twenty-three looms	17·25	
One brusher	0·25	
One drier	0·25	
One shearer	0·50	
One folder	0·25	18·50
SECOND FLOOR.		
Two small pickers	0·50	
Six set of cards	7·50	8·00
THIRD FLOOR.		
Three self-operating jacks	2·50	
One hand jack	0·50	
One wool picker	2·00	5·00
Total net horse power of all the machines		49·75
Friction load, all the machines off	27·50	
Increase due load	2·00	29·50
Maximum horse power, total load		79·25
Percentage of friction to total load		37 per cent.
Percentage of friction to average load		46 per cent.

The motive power was old style, consisting of an 18″×42″ horizontal engine running at fifty-two revolutions per minute, fitted with a box slide valve and a pair of riding cut-offs working in an independent steam chest.

The steam was furnished by two cylinder tubular boilers placed in battery, connected below to mud-pipe through which the feed water was supplied; and above to a steam drum, 36 inches diameter by ten feet long, by a *four inch* pipe from each boiler. The shells were sixty inches diameter by fourteen feet long, *filled* with 94 three-inch tubes, the surface of the top row being within *fifteen inches* of the shell. The furnace was divided into two sections by a center wall projecting a foot above the grate surface. Total heating surface in both boilers 2,300 square feet, total grate surface under both boilers 38 square feet.

An evaporative test, covering one day's work, or from 8 o'clock A. M. until noon, and from 1 o'clock until 5 o'clock, and burning Massillon lump coal, gave the following results.

The quality of steam was determined by using a barrel calorimeter with which a number of careful measurements in the course of the day were made as follows:

Minimum of	21 per cent.
Maximum of	27 per cent.

With an average of 25 per cent. of water entrained with the steam, which passed through the engine and was absorbed by the feed water in a spray heater used in connection with the exhaust.

The exhaust steam after passing the heater was conveyed to the dye house, where it was forced into the dye tubs and water tanks in direct contact with the liquid, resulting in a back pressure against the engine piston of from seven to eight pounds.

Total amount of water, in eight hours from tank	28,350	pounds.
Total amount of water entrained with steam	7,090	"
Total amount of water evaporated	21,260	"
Total amount of coal burned	3,200	"
Average temperature feed water at boiler check	156	degrees.
Average temperature gases in uptake	400	"
Average temperature air in fire-room	100	"
Average temperature atmosphere in the shade	86	"
Average temperature of hygrometer, dry bulb	97	"
Average temperature of hygrometer, wet bulb	83	"
Average pressure steam at boiler gauge	63	pounds.
HOURLY QUANTITIES.		
Pounds of coal	400	pounds.
Pounds of water evaporated	2,658	"
ANALYSIS.		
Pounds of water evaporated at 63 pounds pressure and temperature of 156 degrees, to one pound of coal	6·64	pounds.
Equivalent evaporation at atmosphere pressure and temperature of 212 degrees, to one pound of coal	7·22	"
HORSE POWER DEVELOPED.		
Commercial rating (34½ pounds from and at 212°)	84	H. P.

In scanning the above we would call attention to the bad proportion of the boilers, such as crowding the tubes into the upper portion of the shell, thereby allowing but little steam space and reducing the water surface, then providing only four inch opening for the discharge of the steam into the drum from this cramped space with only a few inches from the water surface, resulting in a constant primage or lifting of the water with the steam, while the back pressure on the engine could be avoided by passing the exhaust through pipes in the tanks instead of discharging direct into the water; and in addition to that duty, if the mill was properly piped up to distribute the exhaust steam, there would be an ample supply to heat the whole building in winter with a very slight increase in the amount of fuel burned. From the results brought out by the above tests it shows conclusively that with a proper plant consisting of an economical engine and boilers the mill could be operated on at least one-half the fuel.—*American Engineer.*

NEW ELEMENT OF THE BLOOD.

IN an important paper by Mr. Geo. T. Kemp on this subject, he comes to the conclusion that in addition to the red corpuscles and leucocytes, the blood normally contains a third histological element—the "plaques." These have been variously considered as young red corpuscles; as nuclei floating in the blood; as being derived from the red or the white corpuscles; as being fibrin; and as being globular depositions produced by cooling of the blood; but the author proves that, although strong resemblances exist between the plaques and other histological elements of the blood, there is not yet sufficient evidence to establish a *genetic* connection. The plaques should therefore, at least for the present, be regarded as independent elements. When the blood is drawn, the plaques break down almost immediately, and this is not true of any other element of the blood. This breaking down of the plaques seems intimately connected, in its time relations at least, with the clotting of the blood. If a good sized drop of blood from a finger be let fall on a cover glass, and as quickly as possible washed by a good jet of 0·75 per cent. NaCl solution, and then examined under the microscope, the plaques, which have a property of sticking to the glass slip, will be found to fill the field; some will be isolated, some will be in groups; they will now appear glistening and granular, and their contours are jagged, becoming more and more so as time elapses; finally, only a granular mass will be found. If, however, a drop of osmic acid be placed on the finger before the drop of blood be drawn, all the elements will be found presenting their normal appearances, and the plaques will be seen as pale homogeneous structures varying greatly in size, but for the most part about one-third or one-fourth of the diameter of the red corpuscles; they are biconcave, but not as much so as the red corpuscles. Once thus hardened they never change their form, but the plaques first referred to will be found to alter their form very speedily; and *pari passu* with these changes, processes are seen which run out from the granular masses, and when coagulation sets in these processes are nearly always found to be continuous with threads of fibrin. The connection between the breaking down of the blood is not histological, but chemical. The plaques appear to give up a soluble substance which is active in coagulation. This active agent is most probably a *fibrin* ferment. Fibrin is deposited histologically independent of any of the cellular elements of the blood, and when the clot is very scant. The fibrin is seen deposited as long, needle shaped, crystal-like bodies.—*Biolog. Lab., Johns Hopkins Univ.*

HEART BEATS.

THE following is from an interesting lecture given in London, on the mechanism of the heart, by Dr. B. W. Richardson.

The number of the pulsations of the heart in different animals—in fish, frog, bird, rabbit, cat, dog, sheep, horse—was described, and a few comments made on the remarkable slowness of the heart—40 strokes per minute—in the horse. Then the number of pulsations in man at various periods of life, and at different levels, from the level of the sea up to four thousand feet above sea level, was brought under review, and was followed by a computation of the average work performed by the heart in a healthy adult man. The work was traced out by the minute, the hour, and the day, and was shown to equal the feat of raising 5 tons 4 cwt. one foot per hour, or 125 tons in twenty-four hours. The excess of this work under alcohol in varying quantities formed a corollary to the history of the work of the heart, Parkes' calculation showing an excess of 24 foot tons from the imbibition of eight fluid ounces of alcohol. The facts relating to the work of the heart by the weight of work accomplished were supplemented by a new calculation, in which the course of the circulation was explained by mileage. Presuming that the blood was thrown out of the heart at each pulsation in the proportion of 69 strokes per minute, and at the assumed force of 9 ft., the mileage of the blood through the body might be taken at 207 yds. per minute, 7 miles per hour, 168 miles per day, 61,320 miles per year, or 5,150,880 miles in a lifetime of 84 years. The number of *beats* of the heart in the same long life would reach the grand total of 2,869,776,000.

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